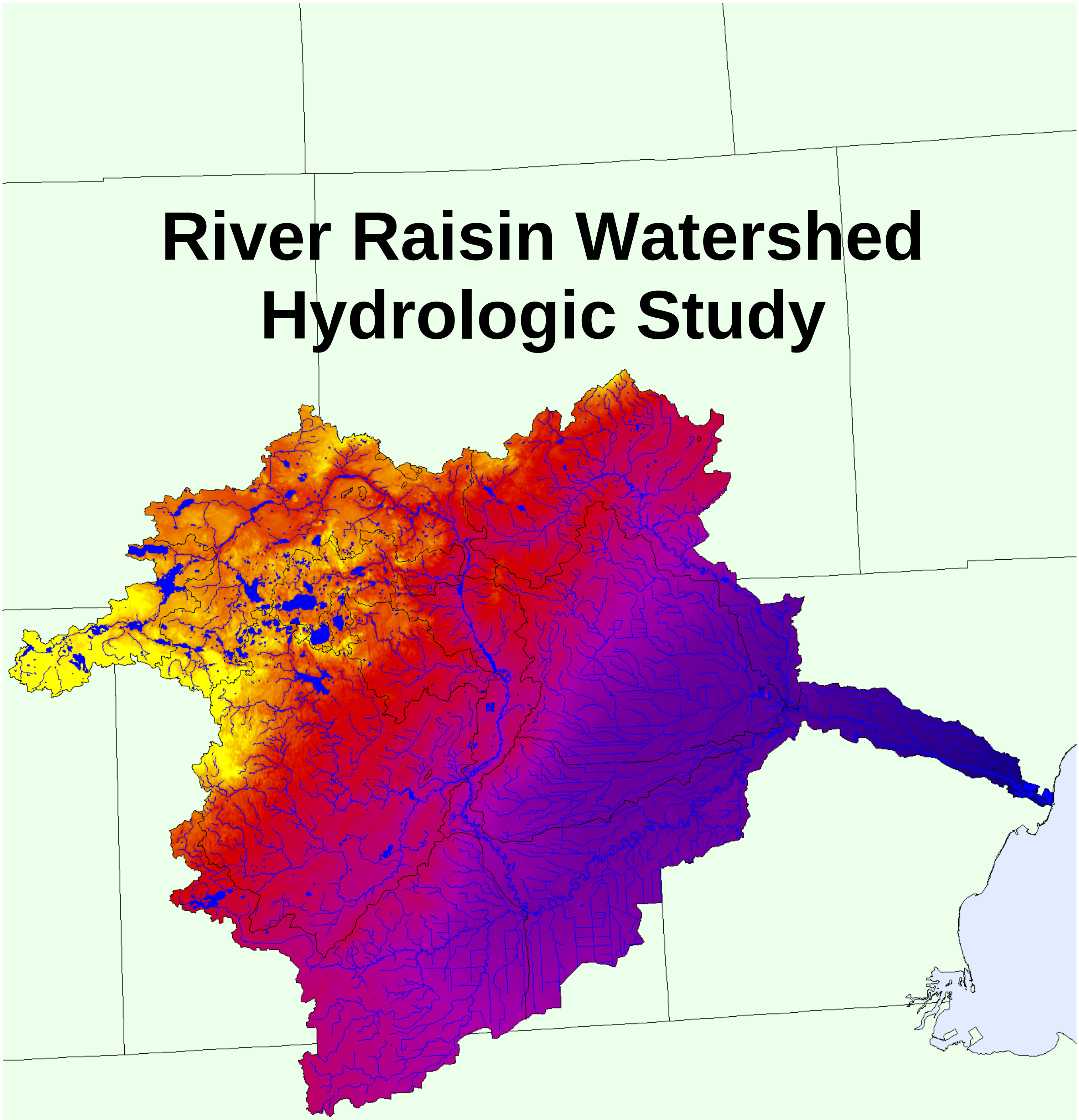
River Raisin Watershed Hydrologic Study



DEQ
Michigan's Nonpoint Source Program

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Michigan Department of Environmental Quality
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This Nonpoint Source Pollution Control project has been funded wholly by the United States Environmental Protection Agency through a Part 319 grant to the Michigan Department of Environmental Quality. The contents of the document do not necessarily reflect the views and policies of the EPA, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use. For more information, go to www.michigan.gov/deqnps.

The cover depicts the drains, streams, lakes, and rivers and ground elevations of the River Raisin Watershed. Lighter colors are higher elevations.

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DEQ Michigan's Nonpoint Source Program

Summary

A hydrologic study of the River Raisin watershed was conducted by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ) in support of a River Raisin Nonpoint Source (NPS) watershed planning project. Using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), a hydrologic model was developed to better understand the watershed's hydrologic characteristics, to provide a basis for stormwater management to protect stream morphology, and to help determine the watershed management plan's critical areas.

Watershed stakeholders may combine this information with other determinants, such as open space preservation, to decide which locations are the most appropriate for wetland restoration, stormwater infiltration or detention, in-stream Best Management Practices (BMPs), or upland BMPs. Local governments within the watershed could also use the information to help develop stormwater ordinances.

The hydrologic study has two land use scenarios corresponding to land cover in 1800 and 1978. General land use trends are illustrated in Figures 1 and 2. Additional land use information is provided in the Watershed Description section and in Appendix A of this report.

The hydrologic modeling quantifies the increases in stormwater runoff volumes and yields, peak flows per drainage area, from 1800 to 1978 throughout the watershed. The increases are due to changes in land use and loss of storage. Detailed discussions of the results are in the Hydrologic Analysis section of this report.

Increases in the runoff volume and peak flow from the 4 percent chance (25-year), 24-hour storm could cause or aggravate flooding problems unless mitigated using effective stormwater management techniques. Increases in the 50 percent chance (2-year), 24-hour storm will increase channel-forming flows. The channel-forming flow in a stable stream usually has a one- to two-year recurrence interval. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows. Hydrologic changes that increase this flow can cause the stream channel to become unstable. Stream instability is indicated by excessive erosion at many locations throughout a stream reach. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm may do little to control the runoff from the 50 percent chance, 24-hour storm, unless the outlet is specifically designed to do so.

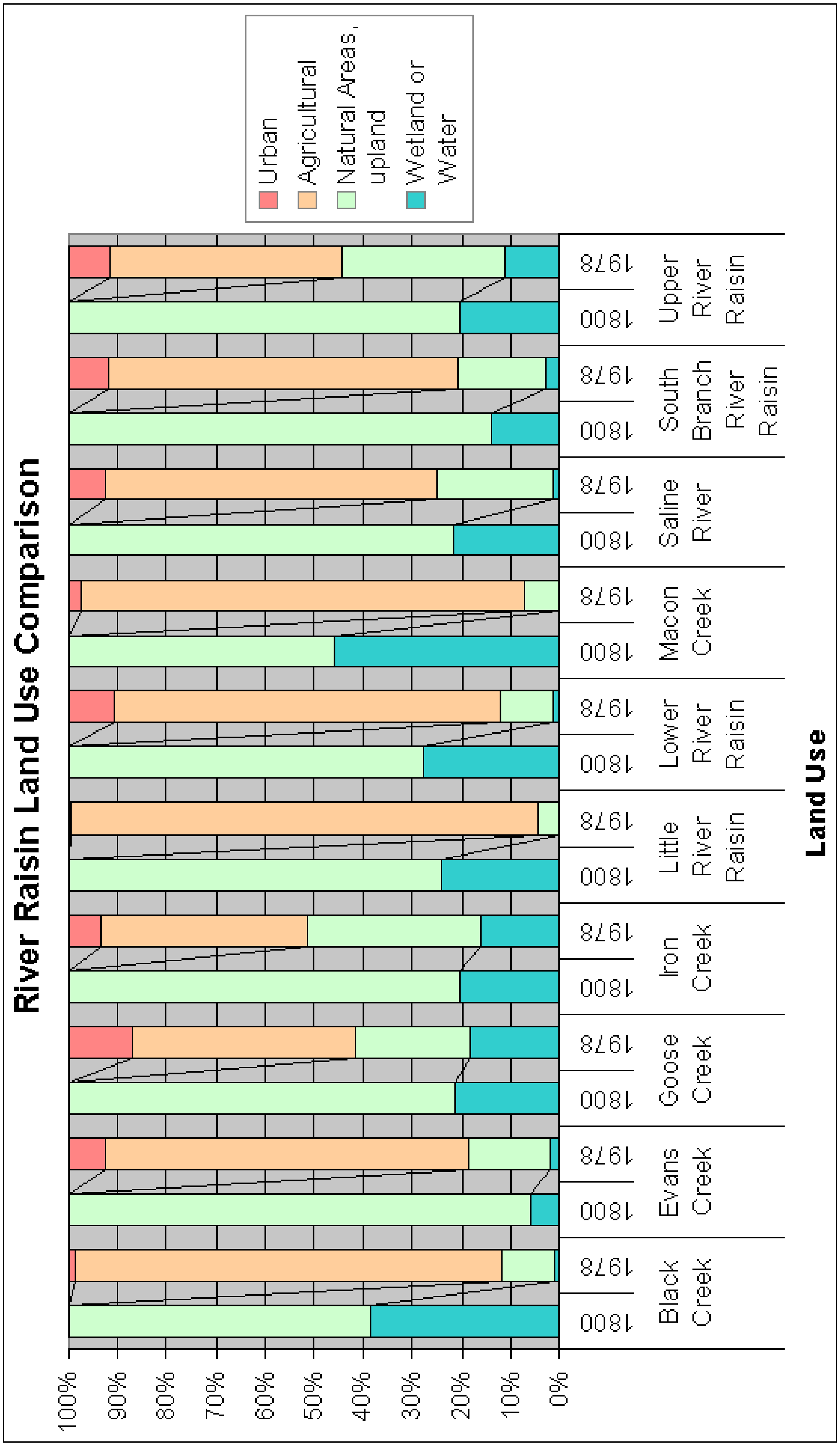

Figure 1: Land Use Comparison, Major Subbasins

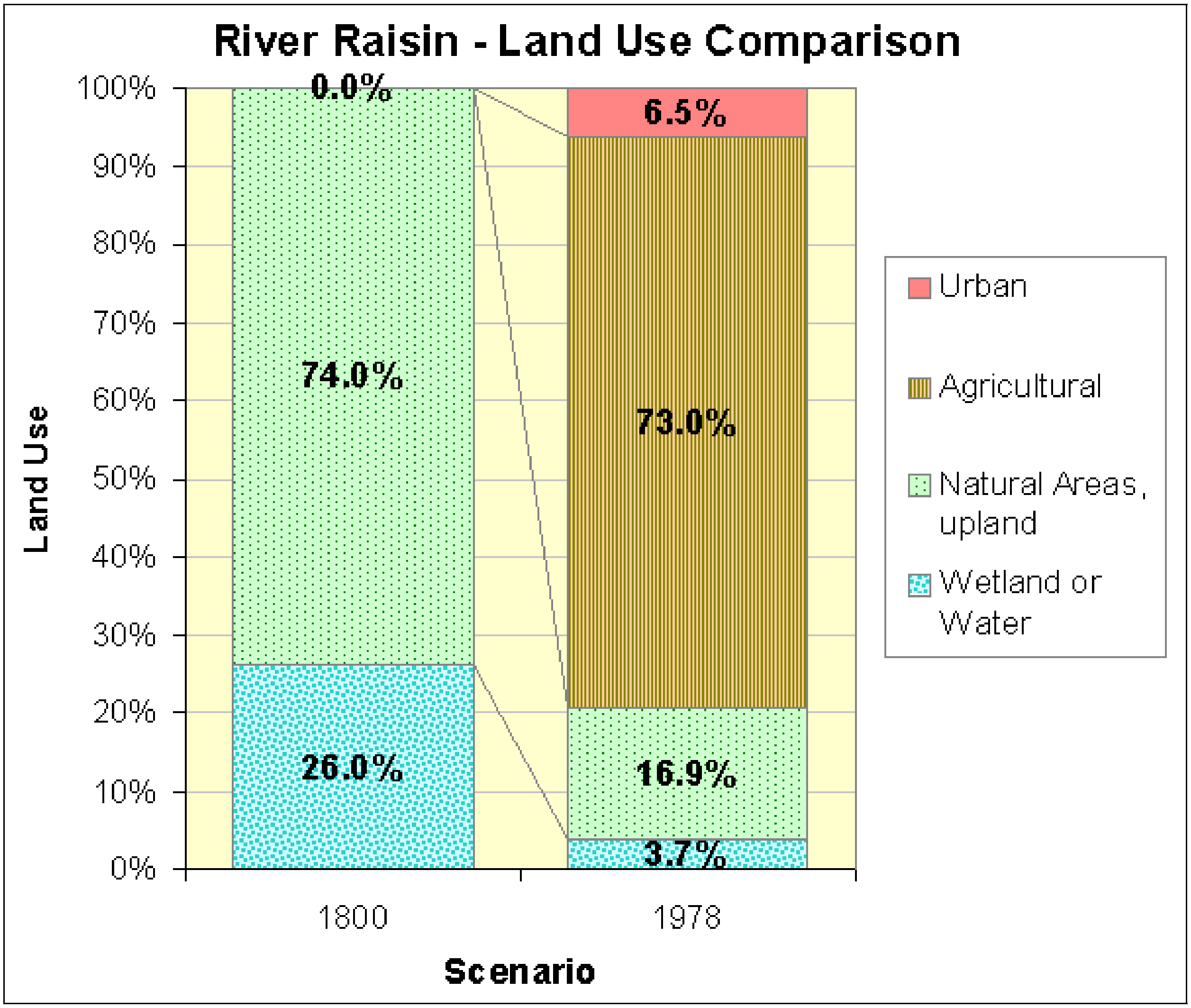

Figure 2: Land Use Comparison, Overall River Raisin Watershed

Project Goals

The River Raisin hydrologic study was initiated in support of the River Raisin Watershed Management Council (RRWMC), which is developing a watershed management plan for the River Raisin watershed. This River Raisin hydrologic study is funded by a United States Environmental Protection Agency (USEPA) Part 319 grant administered by the MDEQ. The goals of this River Raisin study are:

- To better understand the watershed's hydrologic characteristics and the impact of land use changes in the River Raisin watershed on storm flows
- To provide a basis for stormwater management to protect stream morphology
- To help determine the watershed management plan's critical areas – the geographic portions of the watershed contributing the majority of the pollutants and having significant impacts on the waterbody

One focus of this study compares hydrologic characteristics of River Raisin watershed subbasins that are less than 20 square miles. This hydrologic analysis of the subbasins models 1800 and 1978 land use. The 1800 scenario is included to show the impact of land use change, but is not intended as BMP design criteria or as a goal for watershed managers. Runoff from each subbasin for a standard 24-hour storm is calculated for both scenarios. This highlights subbasins that generate a higher proportion of runoff due to soils and land use. Yields, which are peak flows divided by drainage areas, are calculated for each subbasin as a measure of hydrologic responsiveness. To ensure that yield values are comparable, subbasins are similarly sized, and a confidence range is provided based on the drainage area ratio equation used by MDEQ's Hydrologic Studies Unit. A higher yield indicates that the subbasin has comparatively more runoff due to the combination of soils, land uses, storage, and drainage efficiency, and is contributing a proportionately higher flow to the receiving streams. Either yields or runoff volume per area can be used to help select critical areas. Lower values can identify sensitive areas to be protected. Higher values can identify areas that need rehabilitation activities.

Percent imperviousness of each subbasin is analyzed based on land use and population density. The results are compared to the Center for Watershed Protection's proposed classification of headwater urban streams as described in "The Importance of Imperviousness, The Practice of Watershed Protection: Article 1, by Thomas R. Schueler and Heather K. Holland, 2000.

On a larger scale, Richards-Baker flashiness index values were calculated for United States Geological Survey (USGS) gages in the River Raisin watershed. This technique can help identify streams that are becoming flashier during the period of record. In addition, because the Richards-Baker flashiness index is a relatively new technique, exceedences of the 1½ year 24-hour flows were also analyzed, by 10-year intervals, for comparison.

To provide a basis for stormwater management practices and ordinances to protect channel morphology, the Center for Watershed Protection's recommendation of 24-hour extended detention of the one-year 24-hour storm event will be assessed. This analysis is by climatic region. The River Raisin is predominately in region 10, which encompasses Genesee, Lapeer, St. Clair, Livingston, Oakland, Macomb, Washtenaw, Wayne, Lenawee, and Monroe counties.

Watershed Description

The 1,067 square mile River Raisin watershed (Figures 3 and 4) outlets to Lake Erie near Monroe and is located in Hillsdale, Jackson, Lenawee, Monroe, and Washtenaw counties.

This River Raisin study divides the watershed into 117 subbasins, grouped into ten larger subbasins, as shown in Figures 5 and 6. The watershed was modeled using HEC-HMS and the runoff curve number technique to calculate surface runoff volumes and flows from subbasins. This technique, developed by the Natural Resources

Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The technique, as adapted for Michigan, is described in "Computing Flood Discharges For Small Ungaged Watersheds (Sorrell, 2003). Some areas of the watershed are defined as non-contributing, meaning they do not contribute surface runoff during flood events.

The curve numbers for each subbasin, listed in Appendix A, were calculated using Geographic Information Systems (GIS) technology from the digital land use and soil data shown in Figures 7 through 10. Land use maps based on the MDEQ GIS data for 1800 and 1978 are shown in Figures 7 and 8, respectively. Average residential lot size was assumed to be 1/3 acre. The 1800 land use information is provided at the request of the RRWMC. The MDEQ Nonpoint Source Program does not expect or recommend that the flow regime calculated from 1800 land use be used as criteria for BMP design or as a goal for watershed managers.

The NRCS soils data for the watershed is shown in Figures 9 and 10. Where the soil is given a dual classification, B/D for example, the soil type was selected based on land use. In these cases, the soil type is specified as D for natural land uses, or the alternate classification (A, B, or C) for developed land uses. The runoff curve numbers calculated from the soil and land use data are listed in Appendix B. The time of concentration for each subbasin, which is the time it takes for water to travel from the hydraulically most distant point in the watershed to the design point, was calculated from the USGS quadrangles. The same time of concentration values were applied used in both the 1800 and 1978 scenarios.

The design rainfall value used in this study is 2.26 inches, corresponding to the 50 percent chance (2-year), 24-hour storm, as tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129.

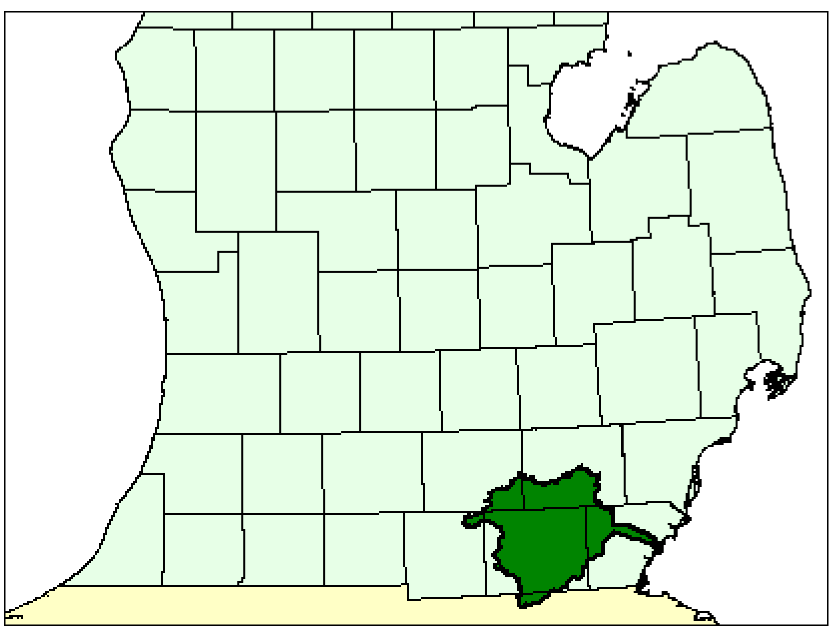

Figure 3: Watershed Location

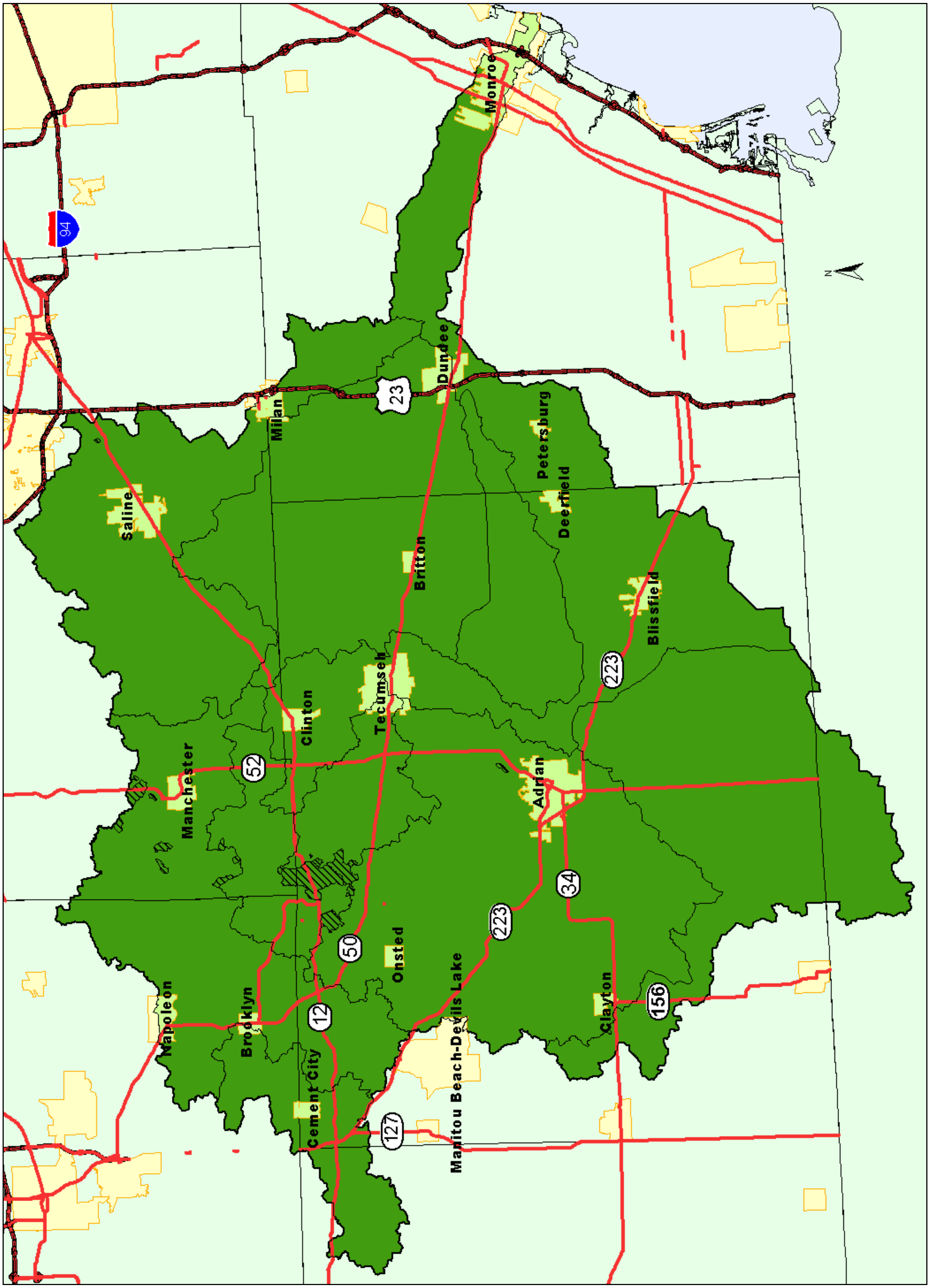

Figure 4: Delineated River Raisin Watershed

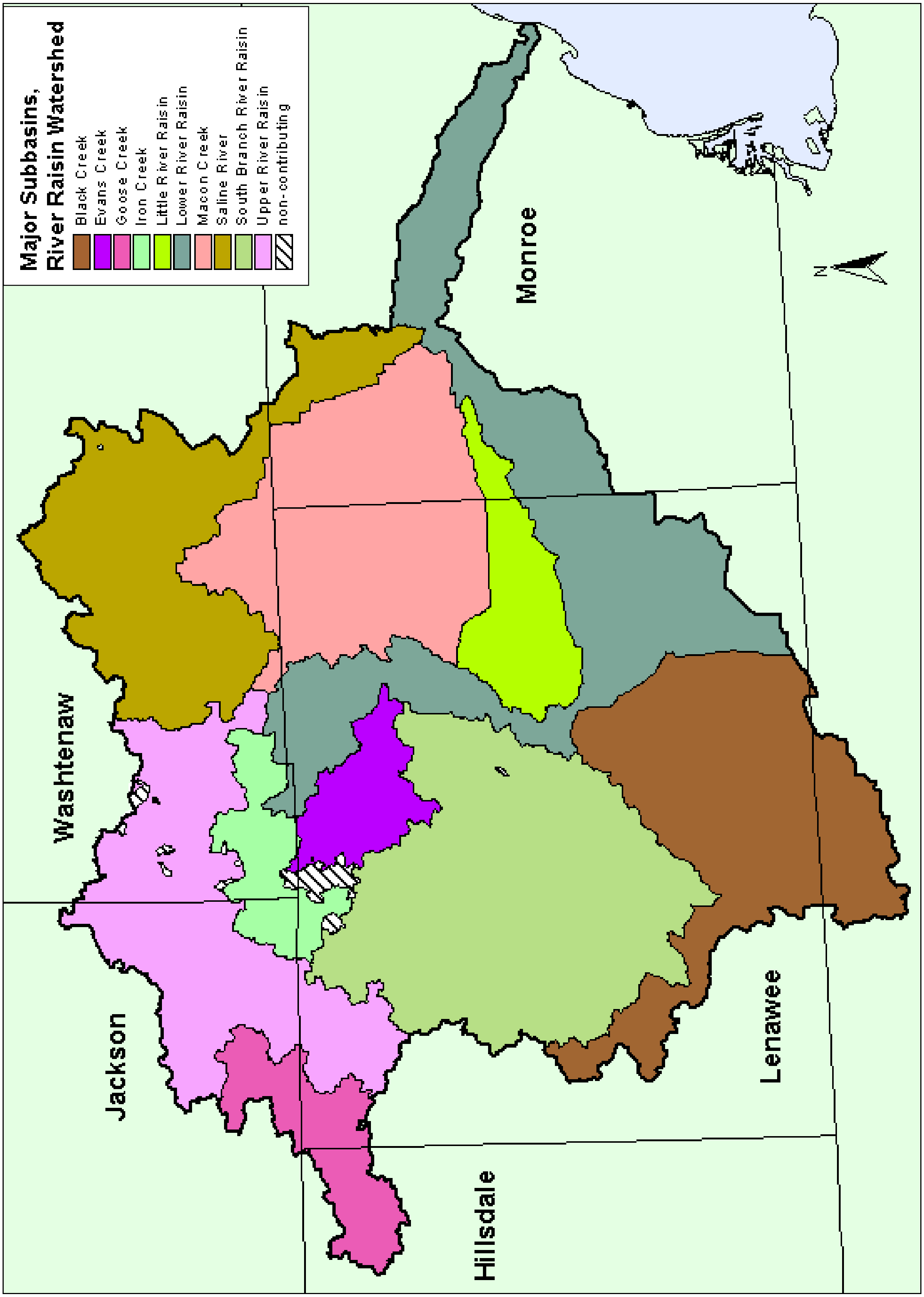

Figure 5: Major River Raisin Subbasins

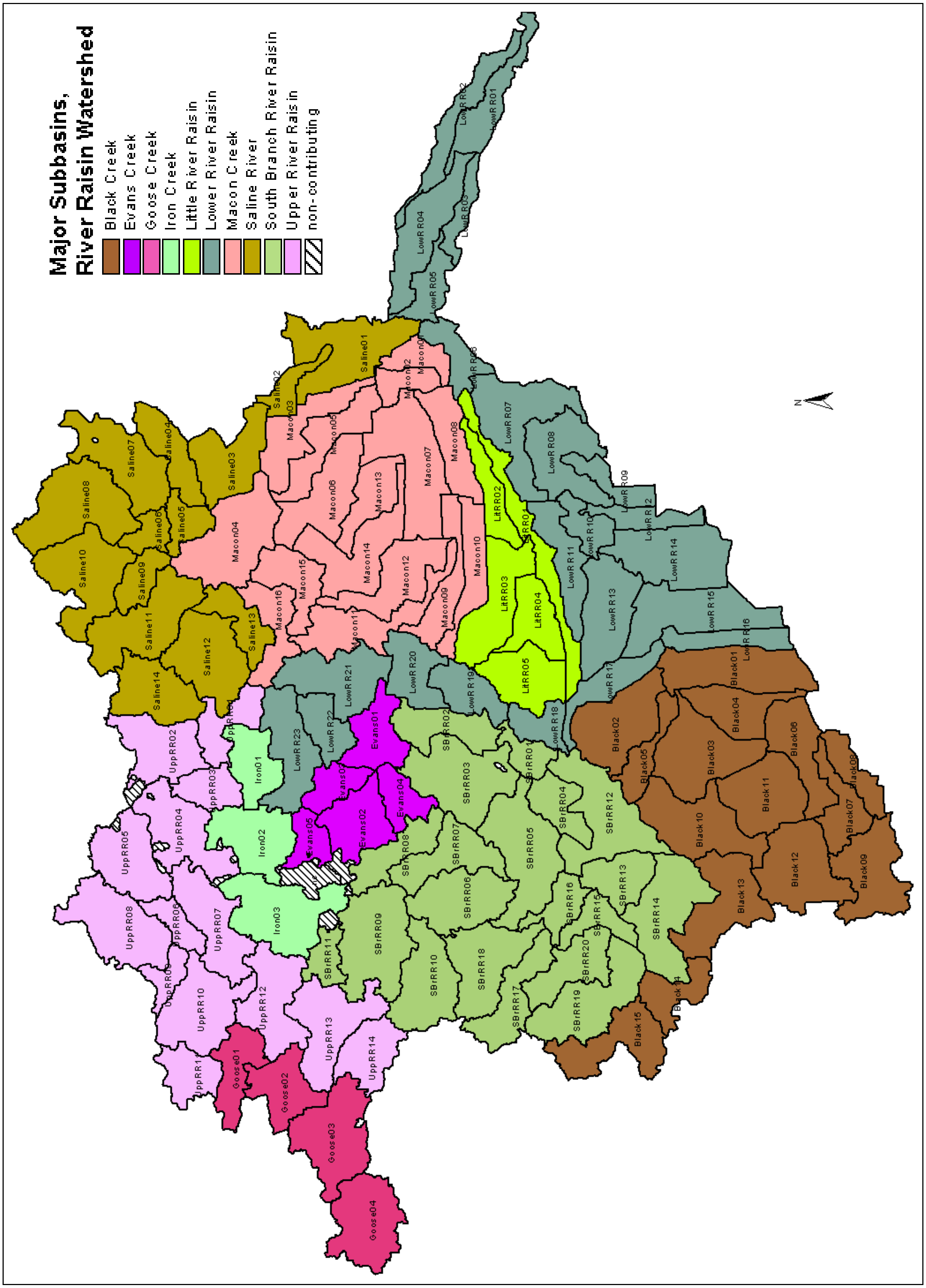

Figure 6: River Raisin Subbasin Identification

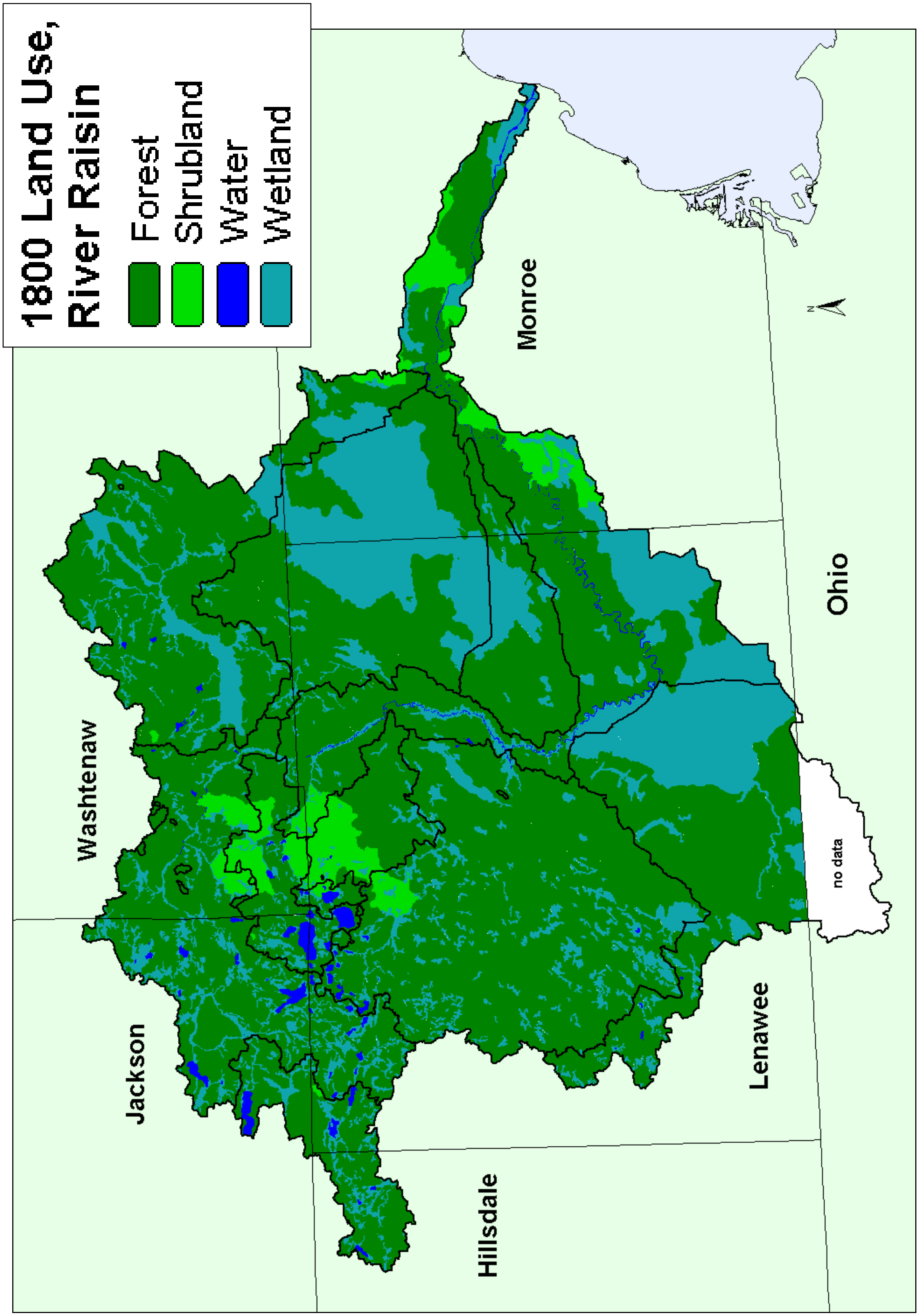

Figure 7: 1800 Land Cover

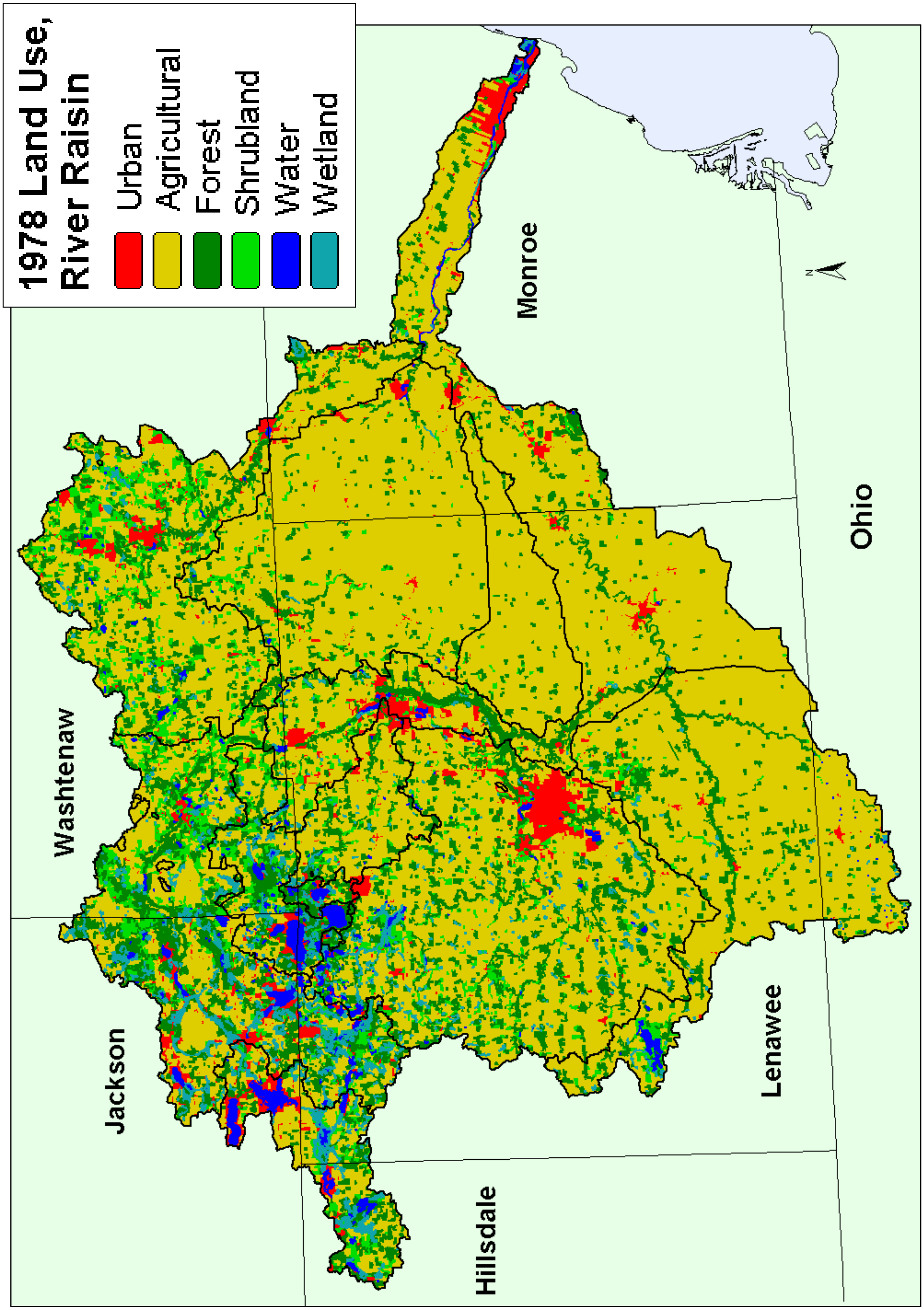

Figure 8: 1978 Land Cover

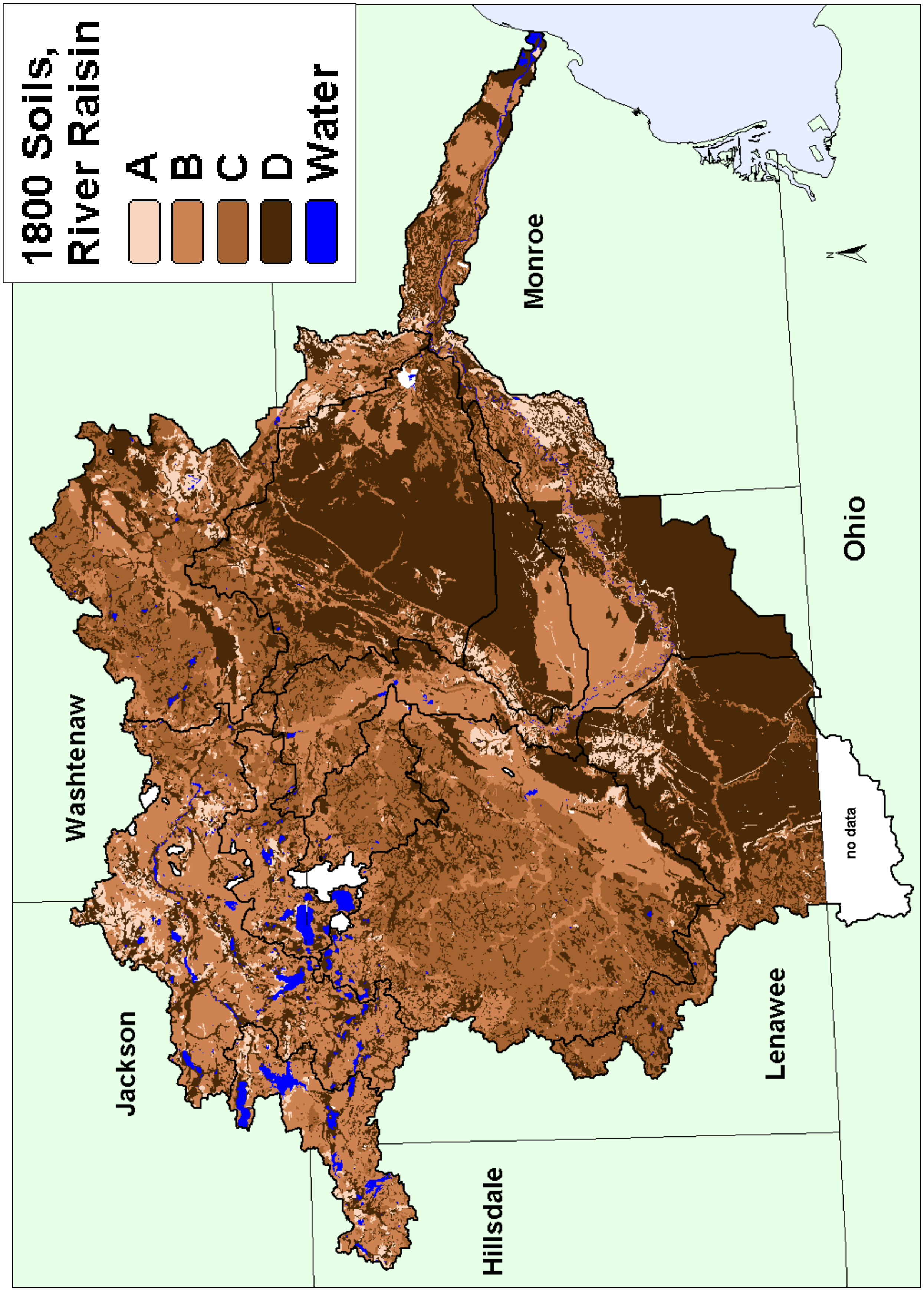

Figure 9: NRCS Soils Data, 1800 Land Cover

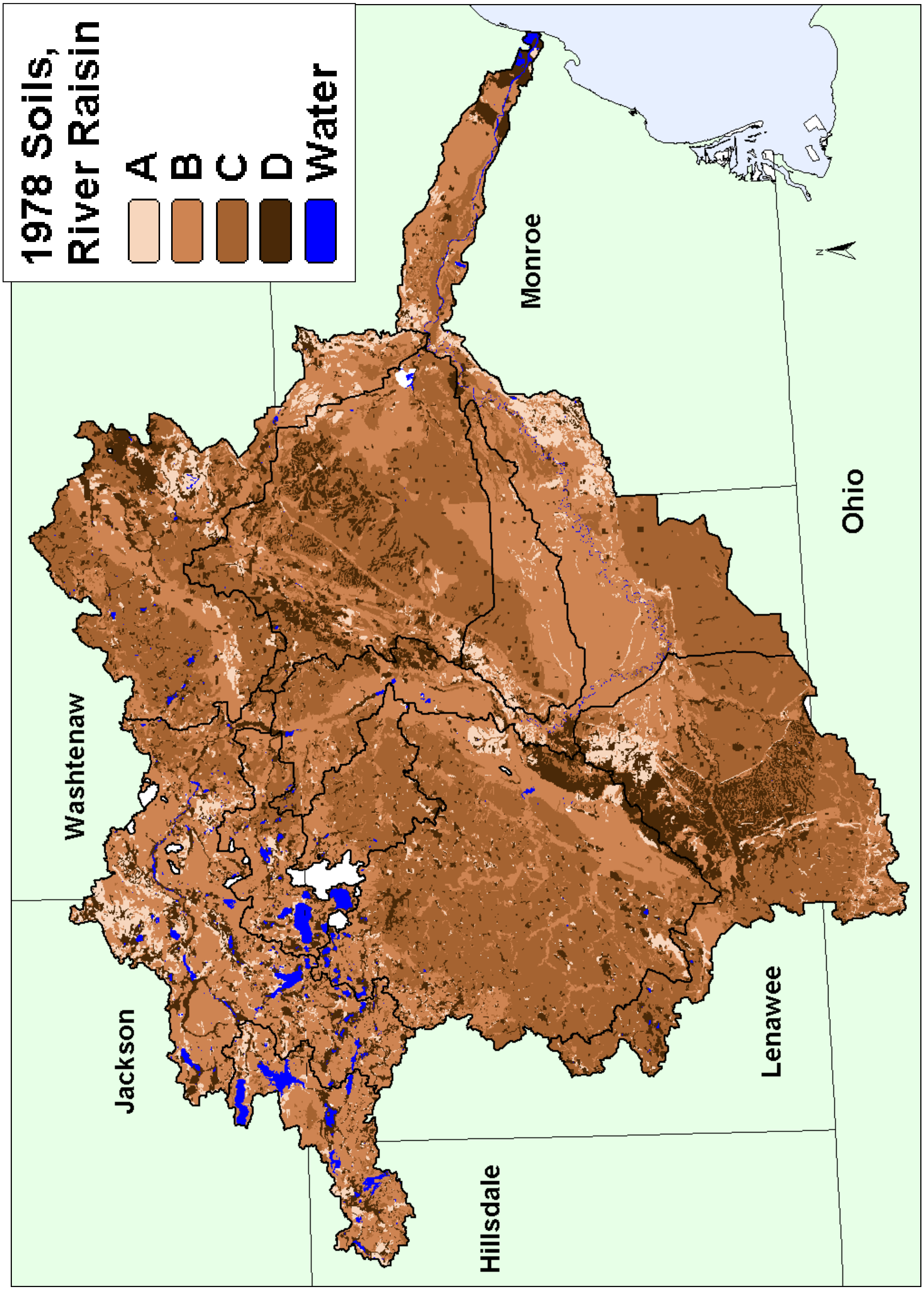

Figure 10: NRCS Soils Data, 1978 Land Cover

Hydrologic Analysis

General Results

Hydrologic modeling shows significant increases in runoff volumes and yields from 1800 to 1978. The increases are due to changes in land use and loss of storage. The increases cause channel erosion and higher flood levels.

Channels are shaped primarily by flows that recur fairly frequently; every one to two years in a stable stream. Bankfull flows are the channel-forming flows in a stable stream. Increases in runoff volumes and peak flows from 1- to 2-year storms increase channel-forming flows, which increase streambank and bed erosion as the stream enlarges to accommodate the higher flows. Increases in runoff volumes and peak flows from less frequent storms, the 4 percent chance (25-year) storm for example, aggravate flooding.

Although most of the modeled land use and storage changes are not recent, the rivers and streams may still be adapting to them. A stream can take 50 years or more to adapt to flow changes (Schueler, 2000, *Dynamics of Urban Stream Channel Enlargement*). A flashiness analysis of USGS gage data, however, indicates that recent hydrologic changes in at least some areas of the River Raisin watershed are continuing to morphologically impact the river.

Future hydrologic changes can continue to impact stream flows, water quality, channel erosion, and flooding. These changes can be moderated with effective stormwater management techniques such as:

- treatment of the “first flush” runoff
- wetland protection
- retention and infiltration of excess runoff
- low impact development techniques
- 24-hour extended detention of 1-year flows
- properly designed detention of runoff from low probability storms

Runoff Volume

One aspect of this study compares hydrologic characteristics of River Raisin watershed subbasins that are less than 20 square miles. Runoff from each subbasin for a standard 50 percent chance 24-hour storm of 2.26 inches is calculated for the 1800 and 1978 scenarios. This storm was selected because runoff from the 50 percent chance storm can be associated with channel-forming flows. For comparison, the calculated runoff volumes are divided by the drainage areas, as shown in Figures 11 and 12, respectively. The units are acre-inches per acre (volume per area), or simply inches.

Changes in runoff per area from 1800 to 1978 are shown in Figure 13. While the results are for a 2.26-inch storm, the trends would be similar for larger storms, although runoff volumes from larger storms will show less of a percentage increase than flows from the 50 percent chance, 24-hour storm.

The results highlight subbasins that generate a higher proportion of runoff due to soils and land use. Runoff volume per area can be used to help select critical areas. Lower values can identify sensitive areas to be protected. Higher values can identify areas that need rehabilitation activities.

The results are also tabulated in Table A2 of Appendix A.

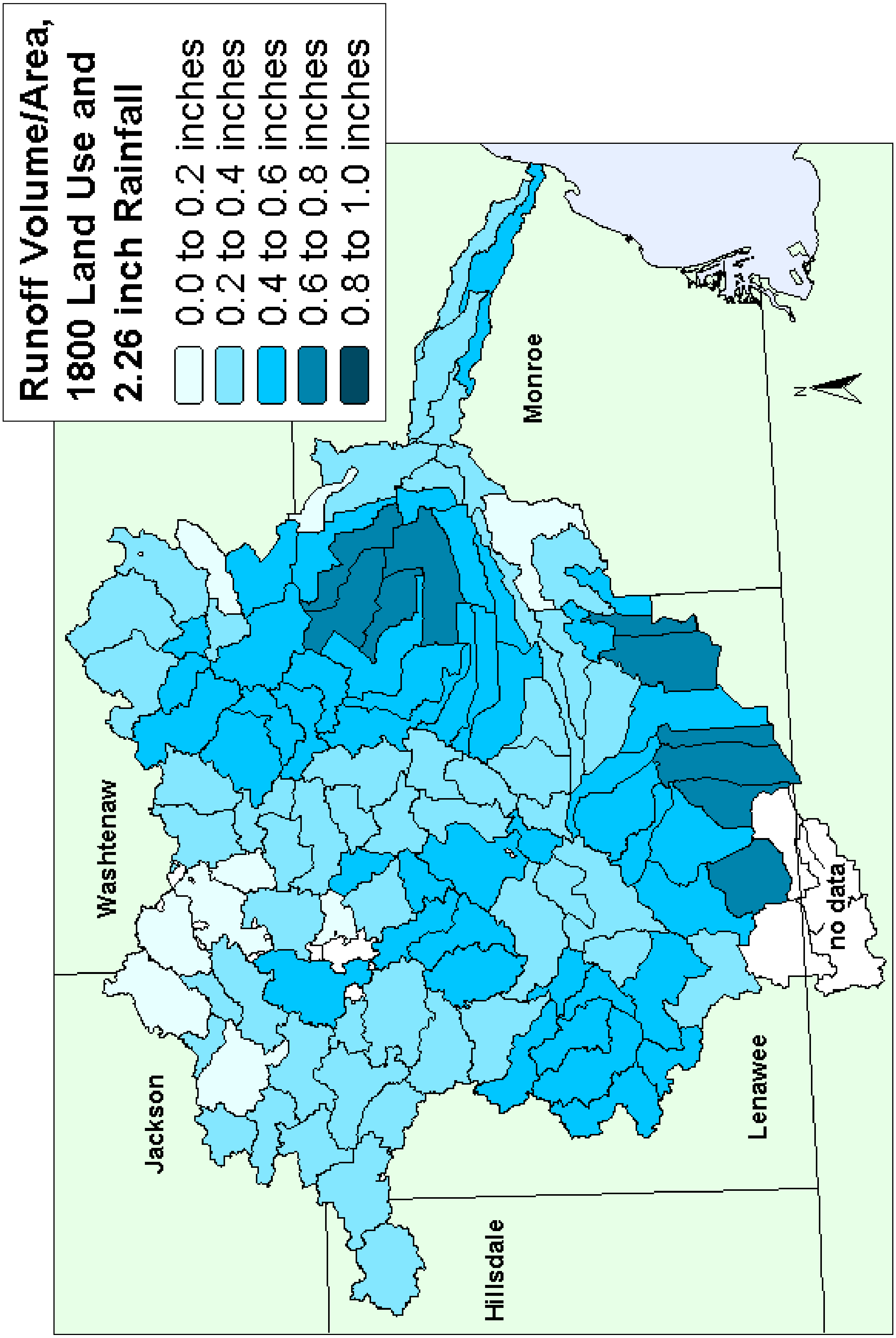

Figure 11: Runoff Volume/Drainage Area, 1800 Land Use

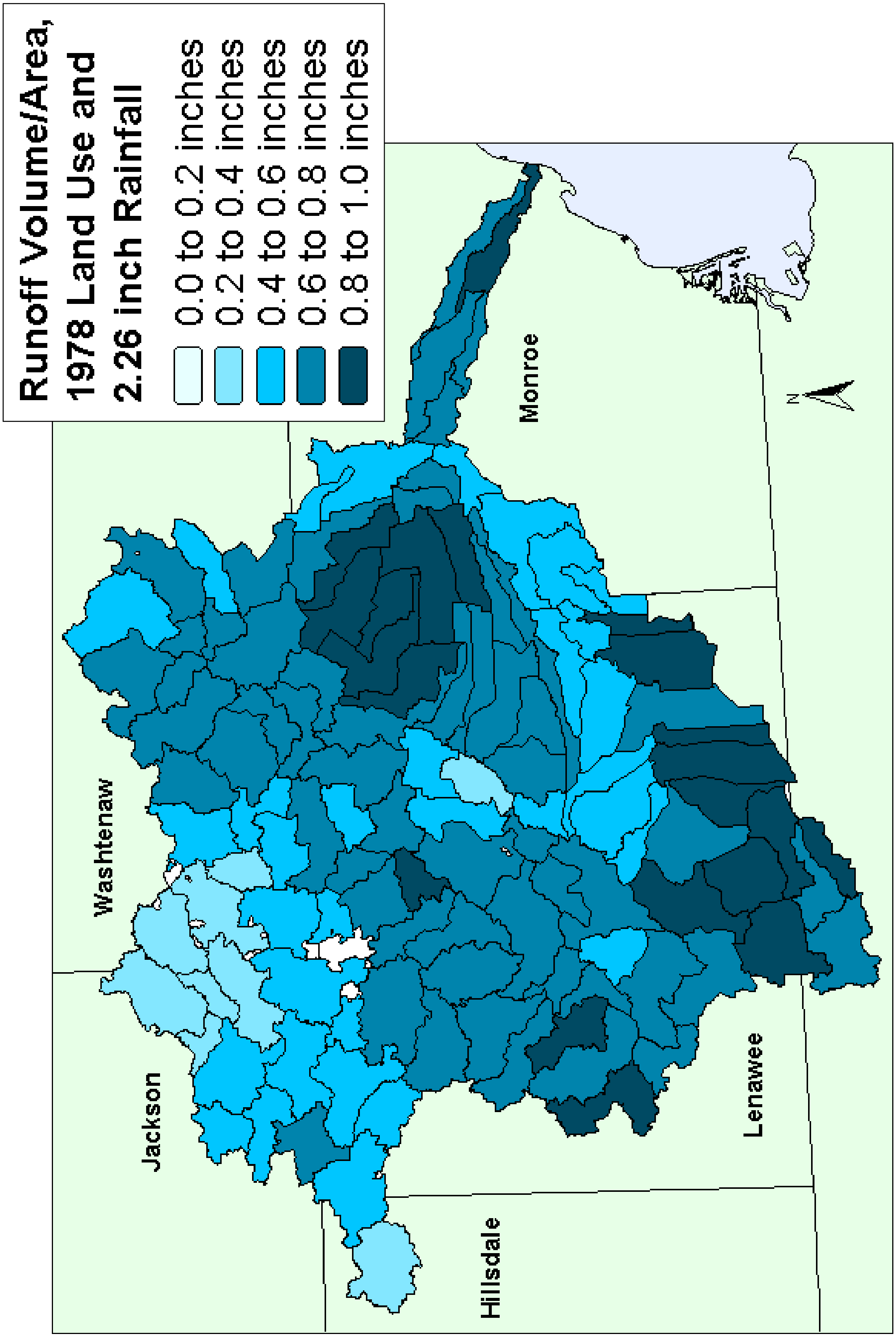

Figure 12: Runoff Volume/Drainage Area, 1978 Land Use

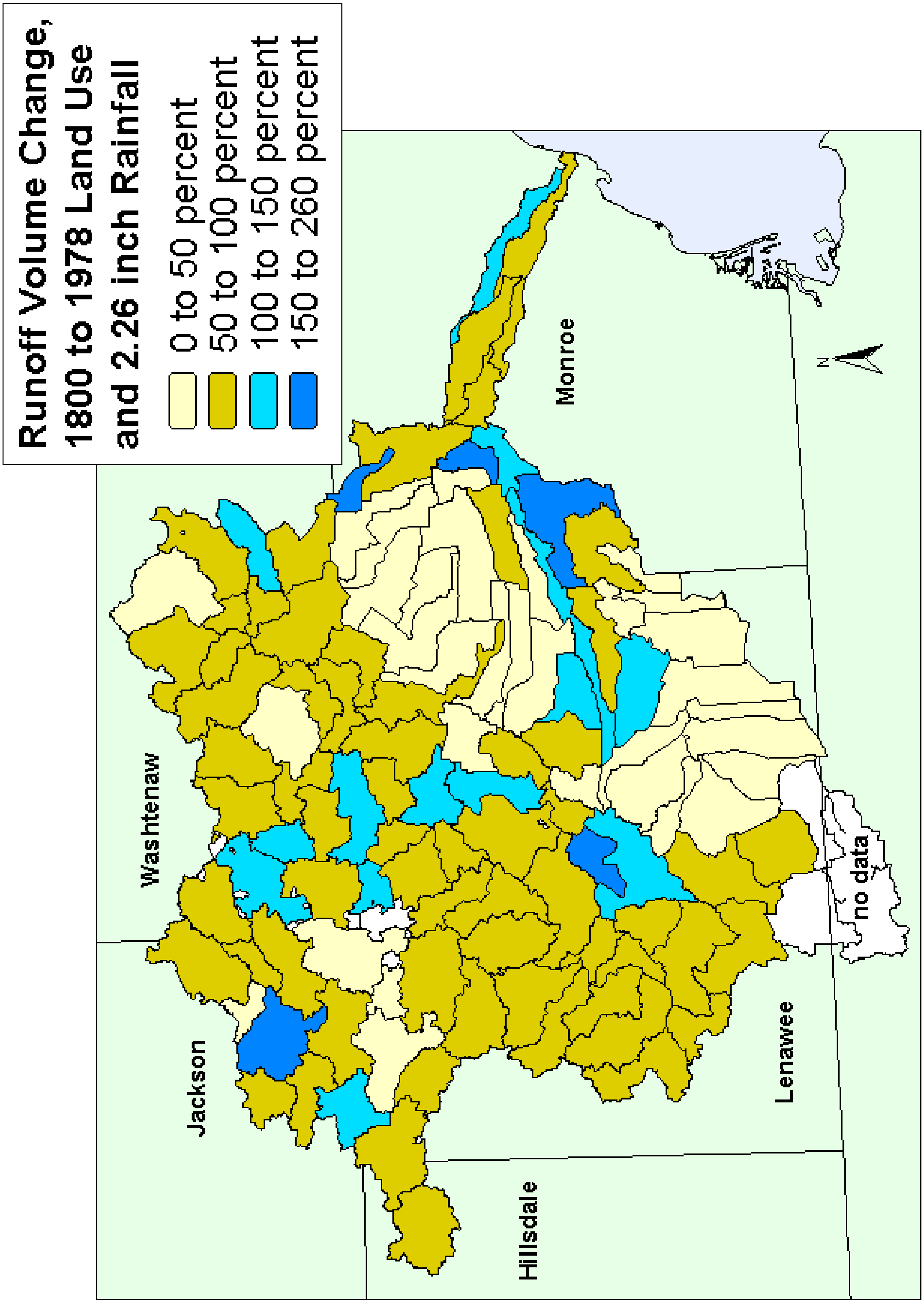

Figure 13: Change in Runoff Volume/Drainage Area, 1800 to 1978 Land Use

Yield Analysis

The preceding runoff analysis accounts only for land use and soils. Yield analysis adds runoff storage, or ponding, and the time it takes for runoff to flow through the subbasin's drainage network. Yield, which is the peak flow divided by the drainage area, is therefore a more complete measure of hydrologic responsiveness. To ensure that yield values are comparable, subbasins are similarly sized, and a confidence range is provided based on the drainage area ratio equation used by MDEQ's Hydrologic Studies Unit. The equation is $Q_2 = Q_1*(A_2/A_1)^{0.89}$. The confidence range adjusts each yield based on the smallest and largest subbasins in the study.

Graphs of the yields and confidence intervals for each subbasin for the 1800 and 1978 scenarios are shown in Figures 14 and 16, respectively. Figures 15 and 17 are maps of the same data using a consistent legend to group the data.

A higher yield indicates that the subbasin has comparatively more runoff due to the combination of soils, land uses, storage, and drainage efficiency, and is contributing a proportionately higher flow to the receiving streams.

Yield changes from 1800 to 1978 are shown in Figure 18. As with the runoff analysis, even though the results are based on one specific storm, the overall trends would be similar for larger storms also, although yields from larger storms will show less of a percentage increase than flows from the 50 percent chance, 24-hour storm. Since both the 1800 and 1978 scenarios use the same time of concentration values, changes in yields do not reflect any changes in drainage efficiency that may have occurred.

Either yields or runoff volume per area can be used to help select critical areas. Lower values can identify sensitive areas to be protected. Higher values can identify areas that need rehabilitation activities.

The results are also tabulated in Table A3 of Appendix A.

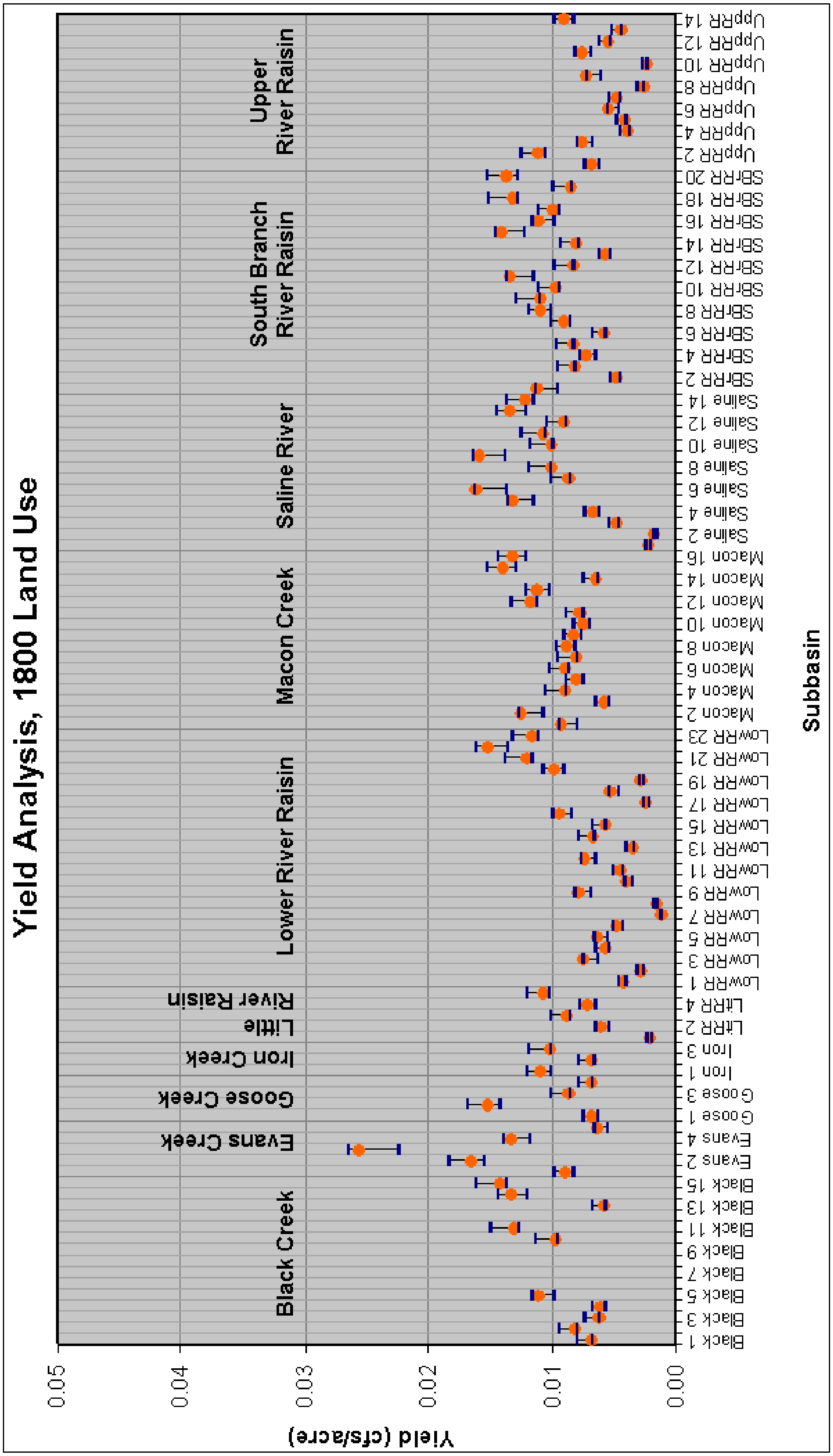

Figure 14: Yield Analysis Chart, 1800 Land Use

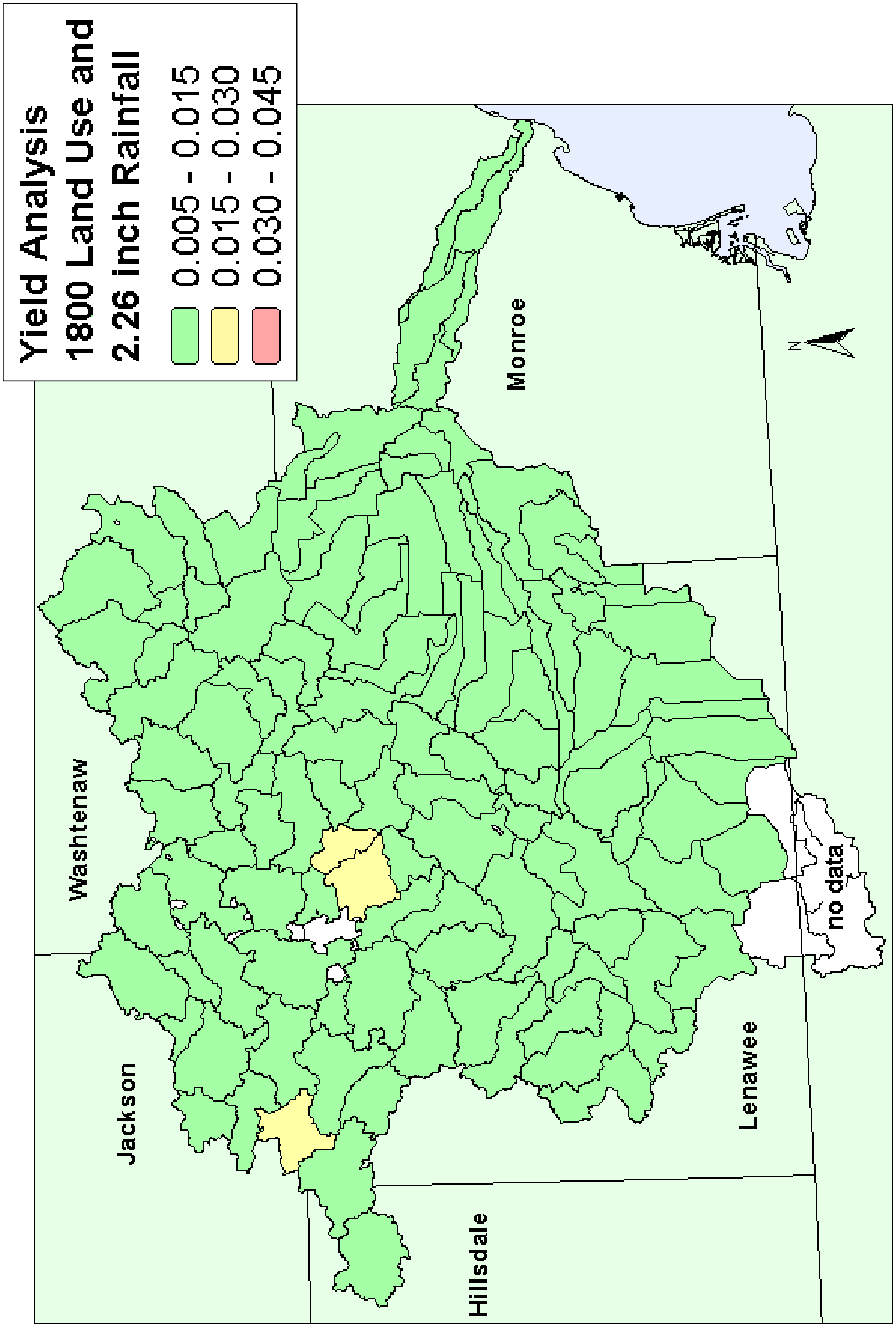

Figure 15: Yield Analysis Map, 1800 Land Use

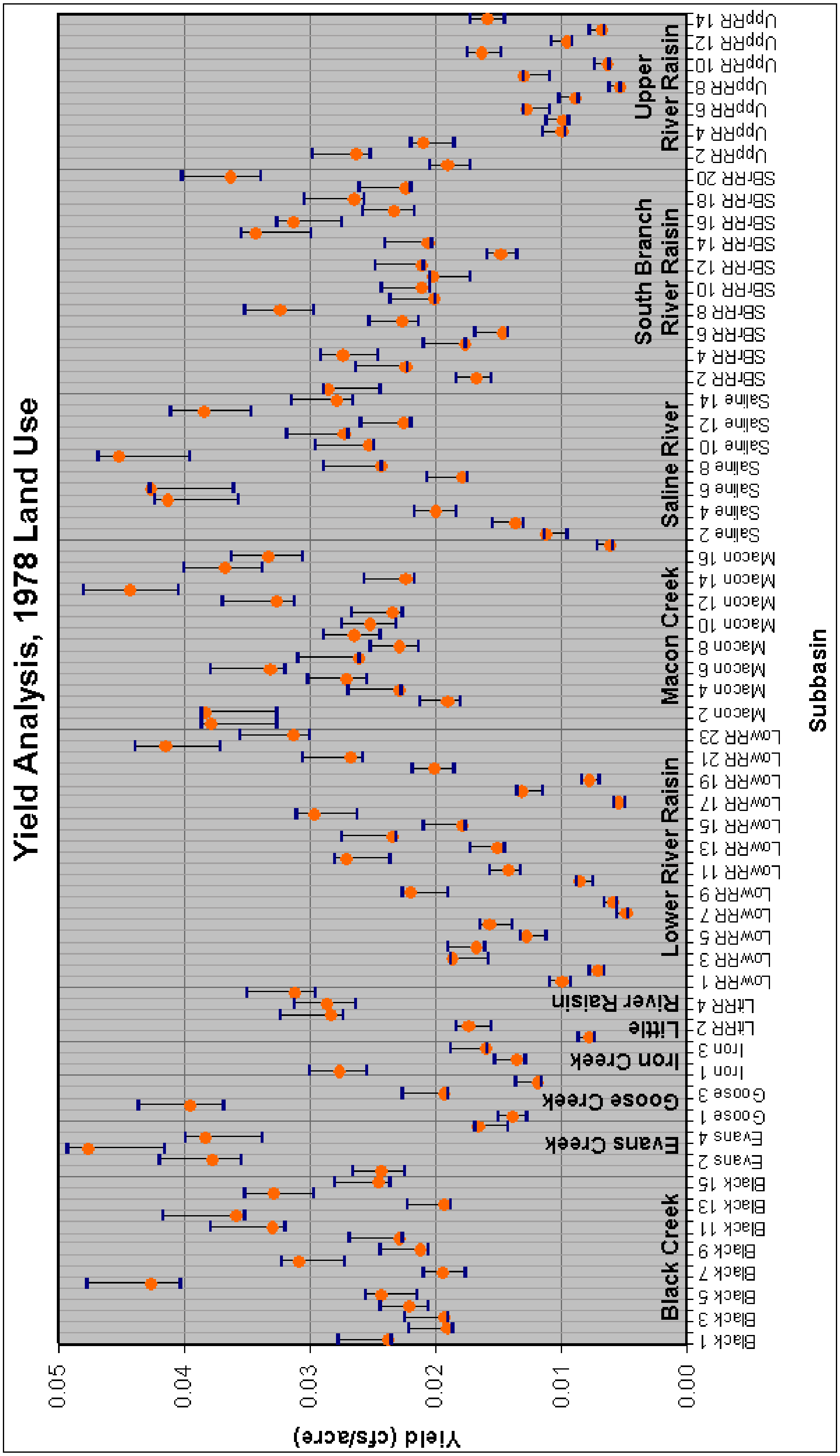

Figure 16: Yields Analysis Chart, 1978 Land Use

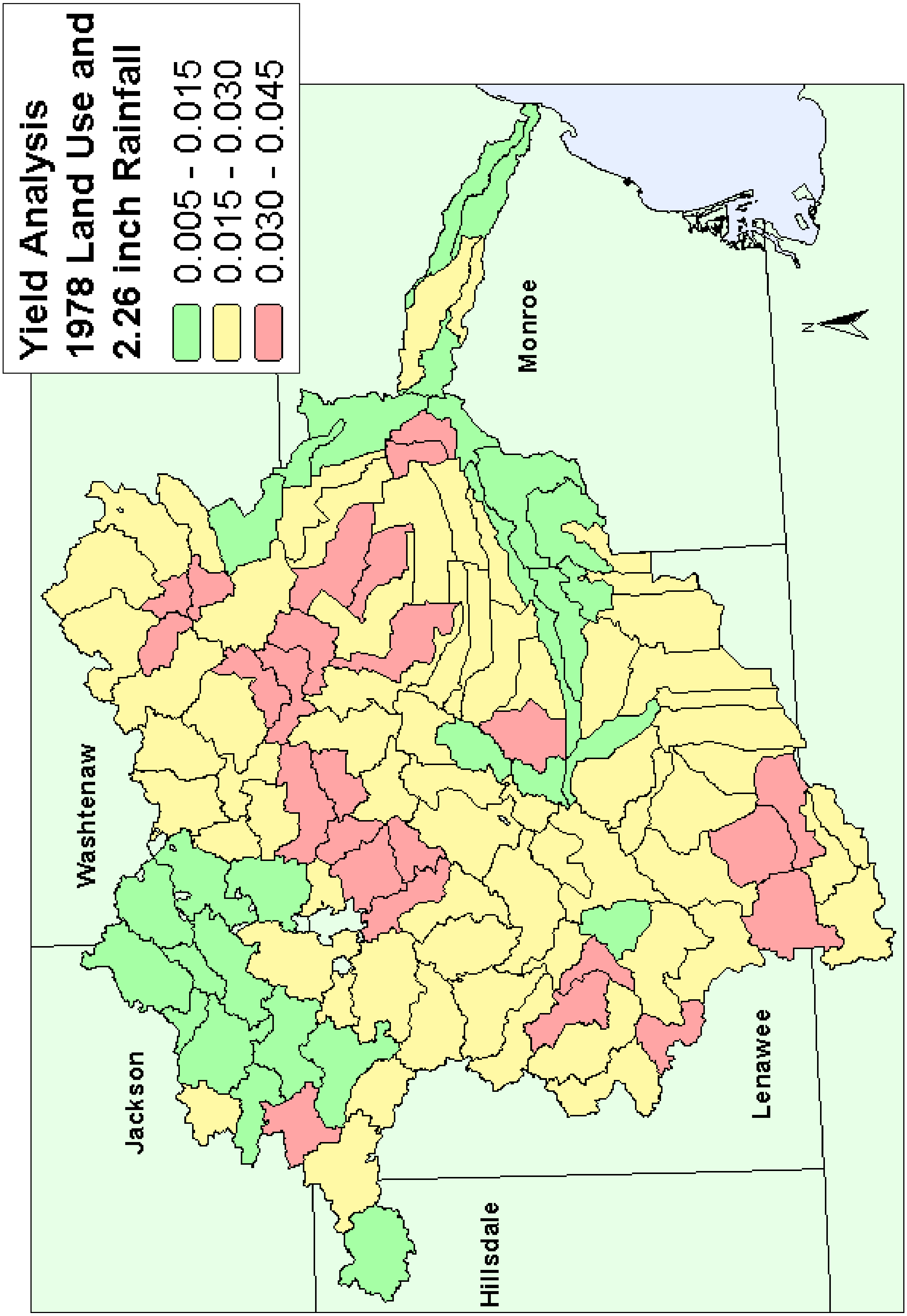

Figure 17: Yields Analysis Map, 1978 Land Use

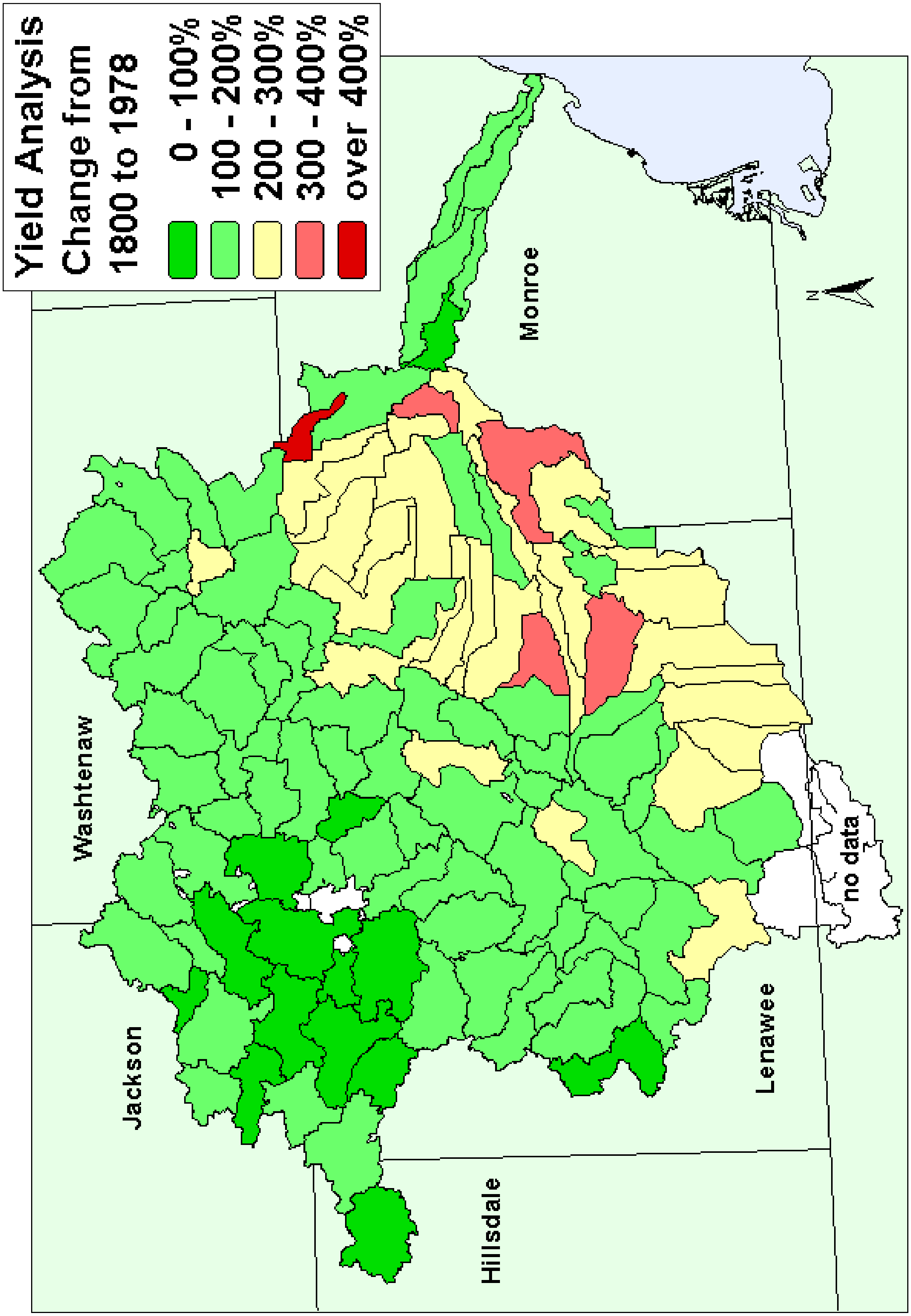

Figure 18: Yields Analysis Map, 1800 to 1978 Land Use

Percent Imperviousness Analysis

Percent imperviousness of each subbasin was analyzed based on the 1978 land use GIS data, Figure 8, 1995 Topologically Integrated Geographic Encoding and Referencing (TIGER) population density data, Figure 19, and the Impervious Surface Analysis Tool (ISAT) extension. The population data is from the Michigan Geographic Data Library, www.mcgi.state.mi.us/mgdl/?action=thm, located under Political Features. The population data was converted to 50 meter grids. ISAT was provided by the National Oceanic and Atmospheric Administration (NOAA), www.csc.noaa.gov/crs/cwq/isat.html. ISAT computed the percent imperviousness according to Table 1. The imperviousness values for residential, commercial, and industrial are from the NRCS (NRCS, 1986).

Table 1: Imperviousness Table for ISAT Analysis

Class	Description	Assigned Imperviousness (percent) by Population Density (people per square mile)		
		Less than 250	250-1000	Over 1000
1	Residential	25	38	65
2	Commercial	85	85	85
3	Industrial	72	72	72
4	Road, Utilities	95	95	95
5	Gravel Pits	0	0	0
6	Outdoor Recreation	0	0	0
7	Cropland	1	1	1
8	Orchard	1	1	1
9	Pasture	1	1	1
10	Openland	0	0	0
11	Forests	0	0	0
12	Open Water	0	0	0
13	Wetland	0	0	0
14	Bare Soil	0	0	0
15	Exposed Rock	0	0	0

The percent imperviousness results can be compared to the Center for Watershed Protection's proposed classification of headwater urban streams, excerpted in Table 2 and detailed in *The Importance of Imperviousness, The Practice of Watershed Protection* (Schueler and Holland, 2000).

The results, shown in Figure 20, indicate that two subbasins are more than 25 percent impervious and five are between 10 and 25 percent. Watersheds approaching the 10 percent threshold are also highlighted in Figure 20.

The results are also tabulated in Table A4 of Appendix A.

Table 2: Classification of Urban Headwater Streams

Urban Stream Classification	**Sensitive (0–10% Impervious)**	**Impacted (11–25% Impervious)**	**Non-supporting (26–100% Impervious)**
Channel Stability	Stable	Unstable	Highly unstable
Water Quality	Good	Fair	Fair-Poor
Stream Biodiversity	Good-Excellent	Fair-Good	Poor
Resource Objective	Protect biodiversity and channel stability	Maintain critical elements of stream quality	Minimize downstream pollutant loads

Excerpted from “The Practice of Watershed Protection” by Thomas Schueler and Heather Holland, p. 15

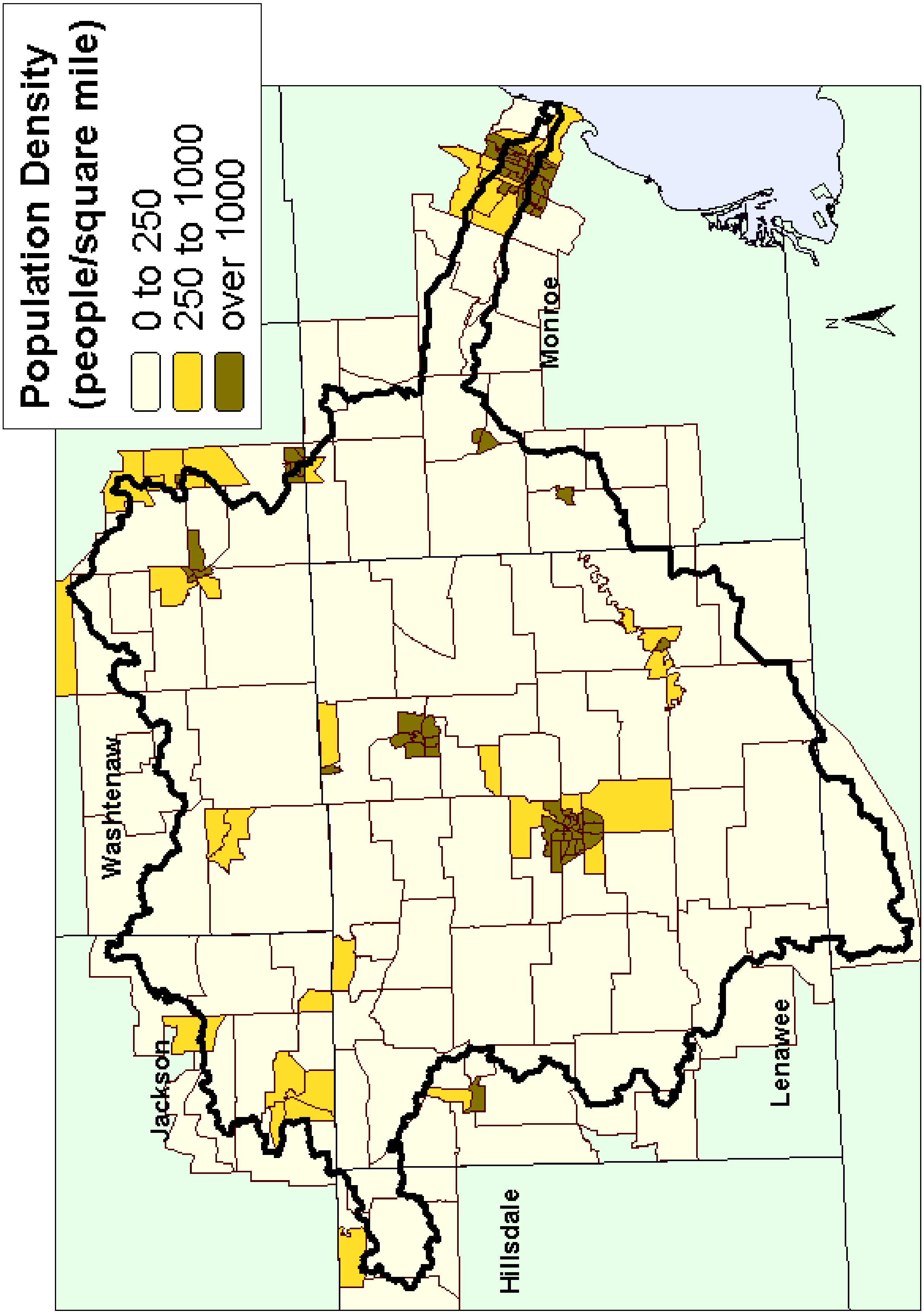

Figure 19: Population Density, 1995 TIGER Census Data

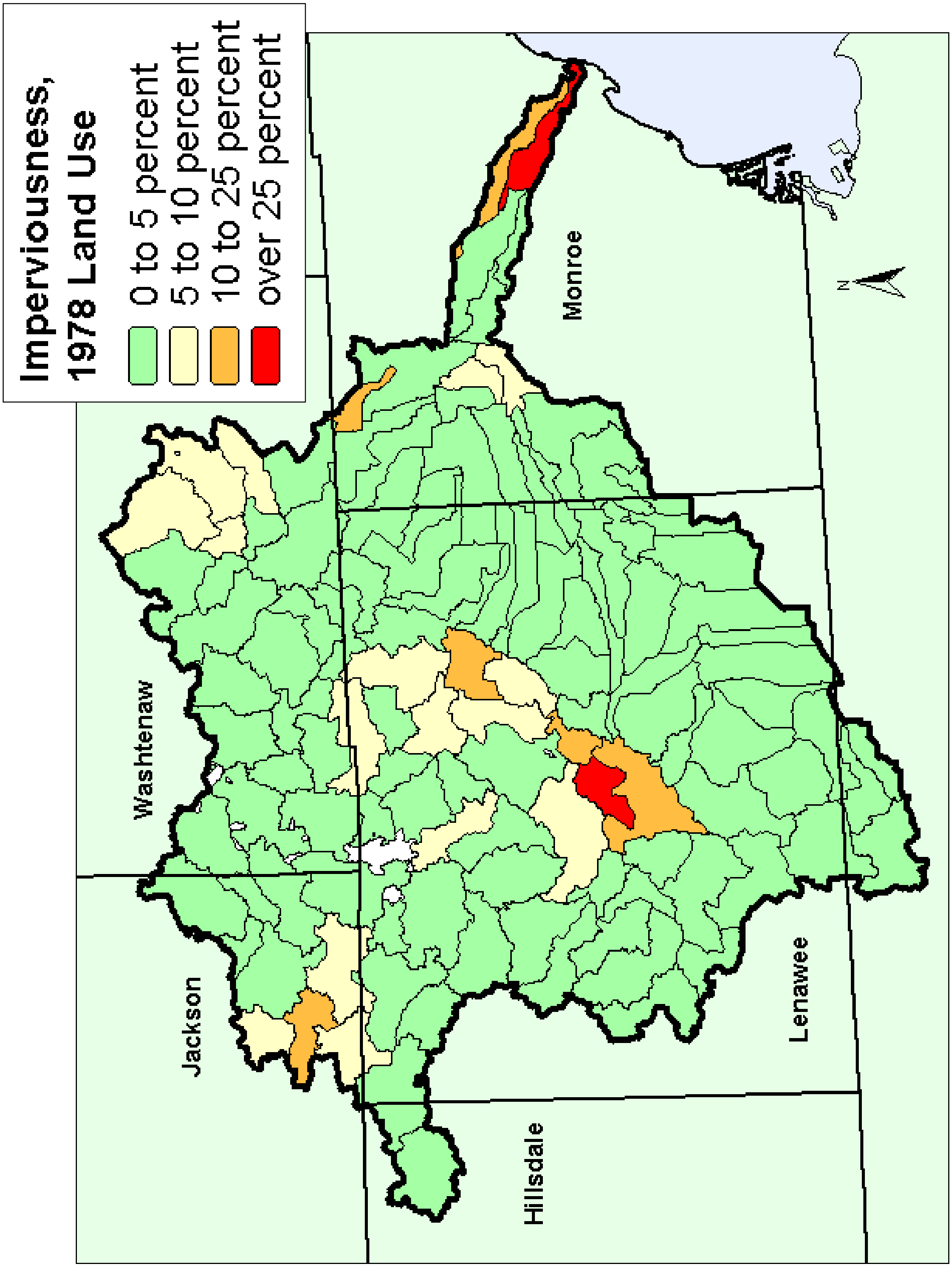

Figure 20: Percent Imperviousness, 1978 Land Use

Flashiness Analysis

Flashiness has no set definition but is associated with the rate of change of flow. Flashy streams have more rapid flow changes. There have been several attempts to classify stream flashiness. For this analysis, we used the methodology detailed in "A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams," published in the Journal of the American Water Resources Association, April 2004, by David Baker, et al. Richards-Baker Flashiness Index values are calculated from mean daily flows. The index values could theoretically range from zero to two, representing constant flow to maximum flow variability, respectively. In reality, all index values will lie between these two extremes. The index value is partially dependent on the size of the watershed. Watersheds are therefore grouped into six sizes for this analysis, as shown in Figure 21. Figure 21 also shows that the index values are divided into quartiles within the watershed size class. Thus, a stream with an index value of 0.25 and a watershed area of over 3,000 square miles would be on the flashy end of the continuum, while the same index value for a stream with an area less than 30 square miles would place it in the stable end. The watershed data in Figure 21 represent 515 streams in six midwestern states (Figure 22).

Flashiness Index values were calculated by water year, October 1 to September 30, for five locations in the River Raisin watershed (Figure 23). Analysis of potential trends was performed on a minimum of 20 years of index values using Microsoft Excel's Regression Analysis ToolPak Add-in. The minimum confidence level is 90 percent, with 95 percent preferred. Potential trendline break points were identified manually. The yearly index values for each gage are plotted in Figures 24 through 28 and detailed in Table A5 in Appendix A. The results, summarized in Table 3 and Figure 29, indicate that, beginning around 1970, hydrologic changes in the watershed above the River Raisin gages near Monroe and Adrian are causing the river at those locations to become flashier, which could cause streambank erosion as the affected stream(s) adapt to the higher flows.

Because the Richards-Baker flashiness index is a relatively new technique, exceedences of the 1½ year 24-hour flows were also analyzed, by 10-year intervals, for comparison. The 1½ year flow was selected because channel-forming flow in a stable stream usually has a one- to two-year recurrence interval. The 1½ years flows, shown in Table 4, were determined by Log Pearson analysis of the gage data. The results (Figure 30) are generally consistent with the Richards-Baker flashiness index trends.

The gage on the River Raisin near Manchester shows no trend using either method. The gage at River Raisin near Tecumseh shows a decreasing flashiness trend with both methods, but the time period is comparatively short and ended in 1980. The gage at the River Raisin near Adrian has an increasing flashiness trend with both methods from 1970 on. The two methods are less consistent for gage at the River Raisin near Monroe, however. The number of exceedences per year appears to be steady for the period of record, but the Richards-Baker flashiness index shows a decreasing trend from 1938 to 1969 and an increasing trend from 1970 to 2004.

Streams may become flashier because of land use changes, either as urban areas expand or as natural areas transition to other uses, or because of loss of ponded storage for runoff, particularly in wetlands. Stream flows may remain stable if the watershed is not experiencing hydrologic changes or if the changes are properly planned to mitigate runoff volume and flow increases.

Results of the flashiness analysis apply only to the years when data is available at each gage. Results of this analysis also do not necessarily apply to tributary streams upstream of the USGS gages. For example, a watershed with stable flashiness index values could nonetheless have an unstable tributary stream or streams. Similarly, a watershed with an increasing flashiness trend may have areas that are stable.

Quartile rankings of the River Raisin gages are based on the 515 midwestern gage sites used in the Richards-Baker report. MDEQ's Nonpoint Source Program is conducting a similar analysis of all Michigan gages. Quartile rankings may change using this set of gages, because an additional three years of data is included. The results will be provided to the River Raisin stakeholders when available.

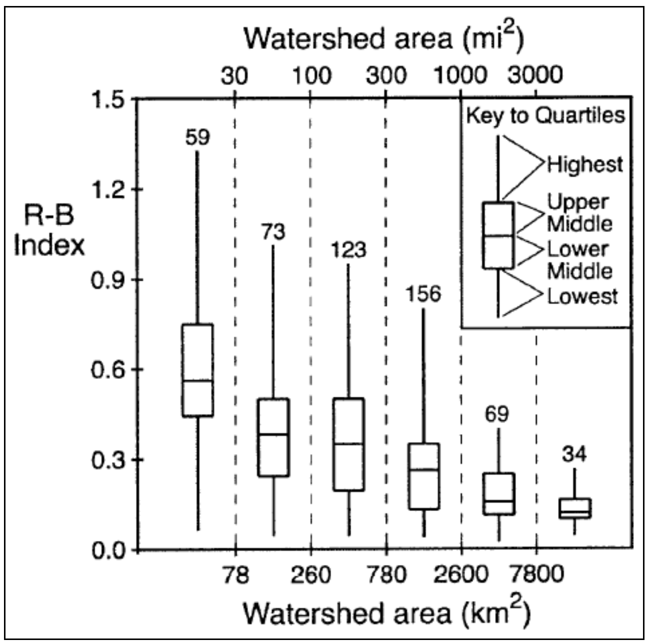

Figure 21: Distribution of Richards-Baker Index Values for Streams in Six Watershed Size Classes, Showing Quartiles of Index Values. The whiskers of the box plots extend to the maximum or minimum values.

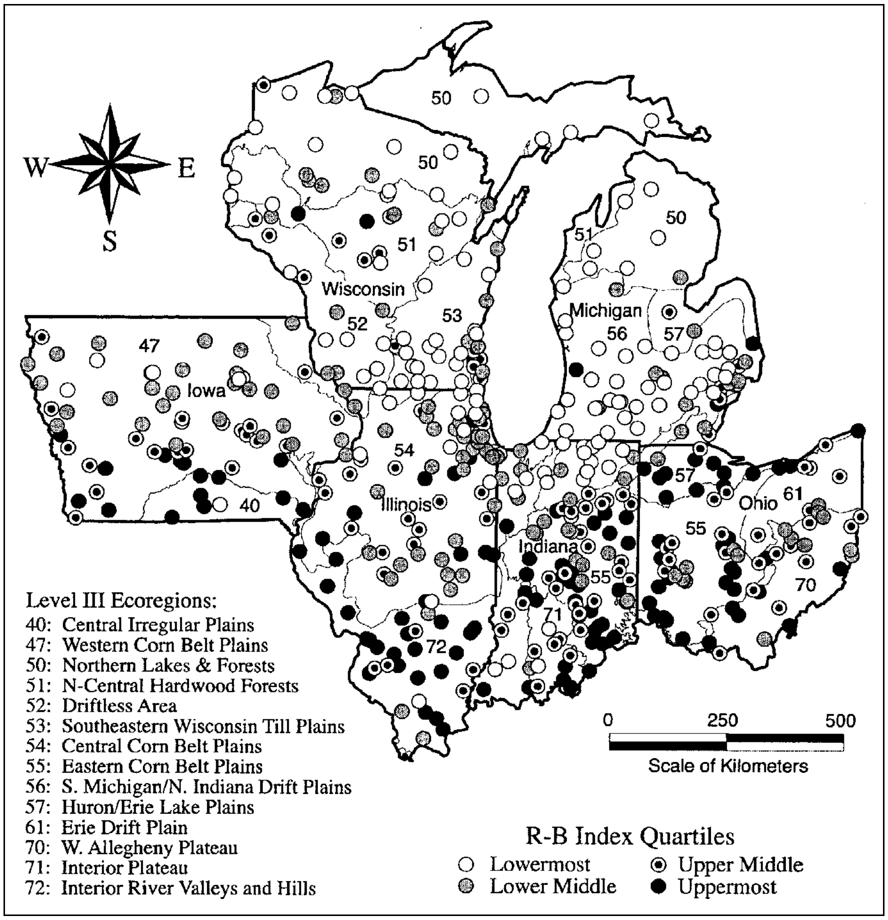

Figure 22: Quartile Rankings of 27-Year Average R-B Index Values Plotted by Location of Stream Gages in Relation to Level III Ecoregions in the Richards-Baker Six State Study Region

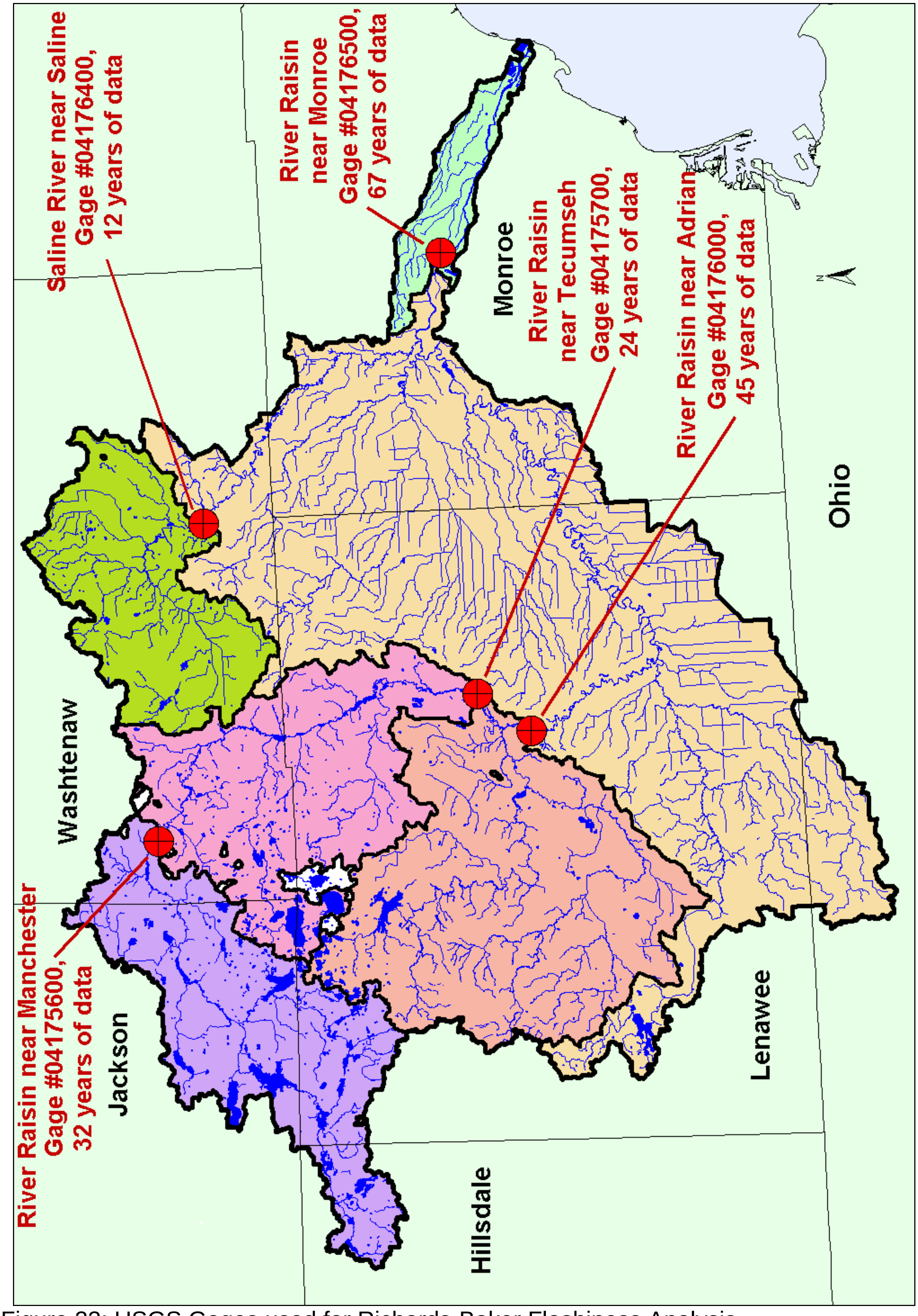

Figure 23: USGS Gages used for Richards-Baker Flashiness Analysis

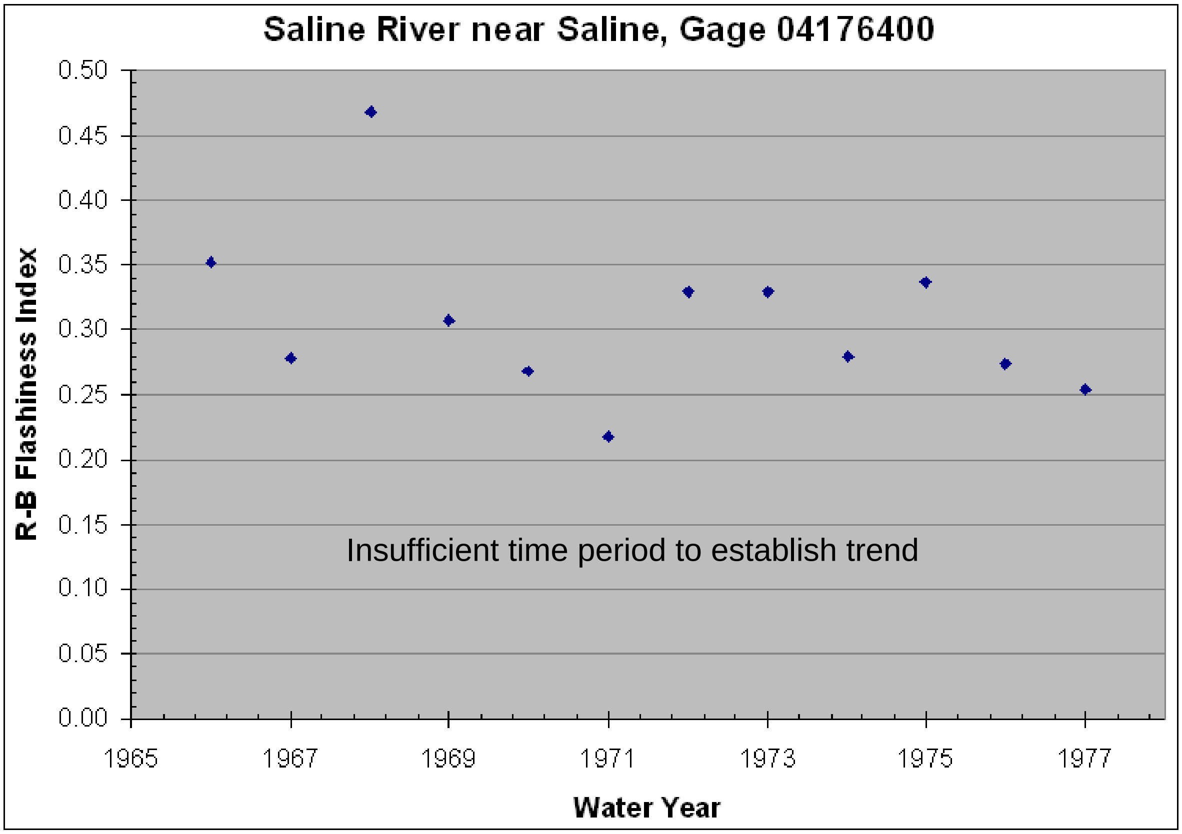

Figure 24: Richards-Baker Flashiness Analysis for Gage 04176400

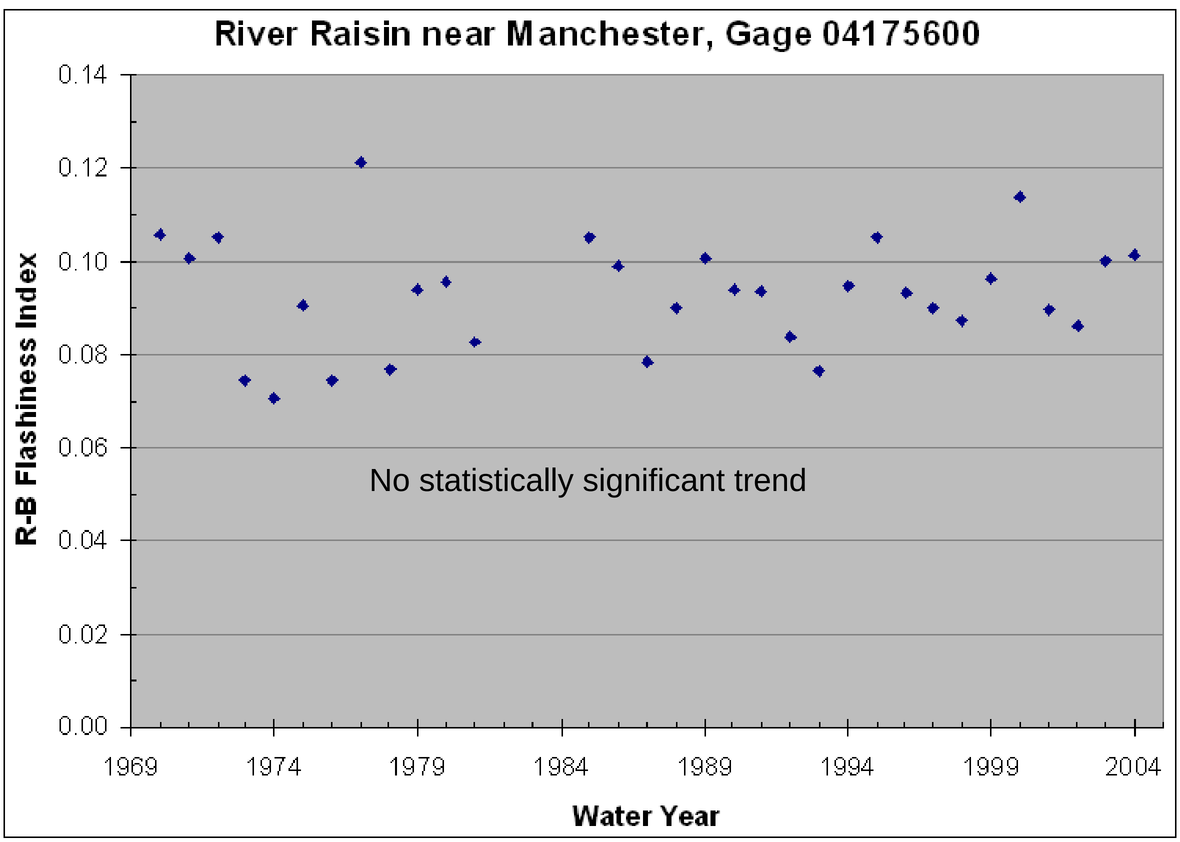

Figure 25: Richards-Baker Flashiness Analysis for Gage 04175600

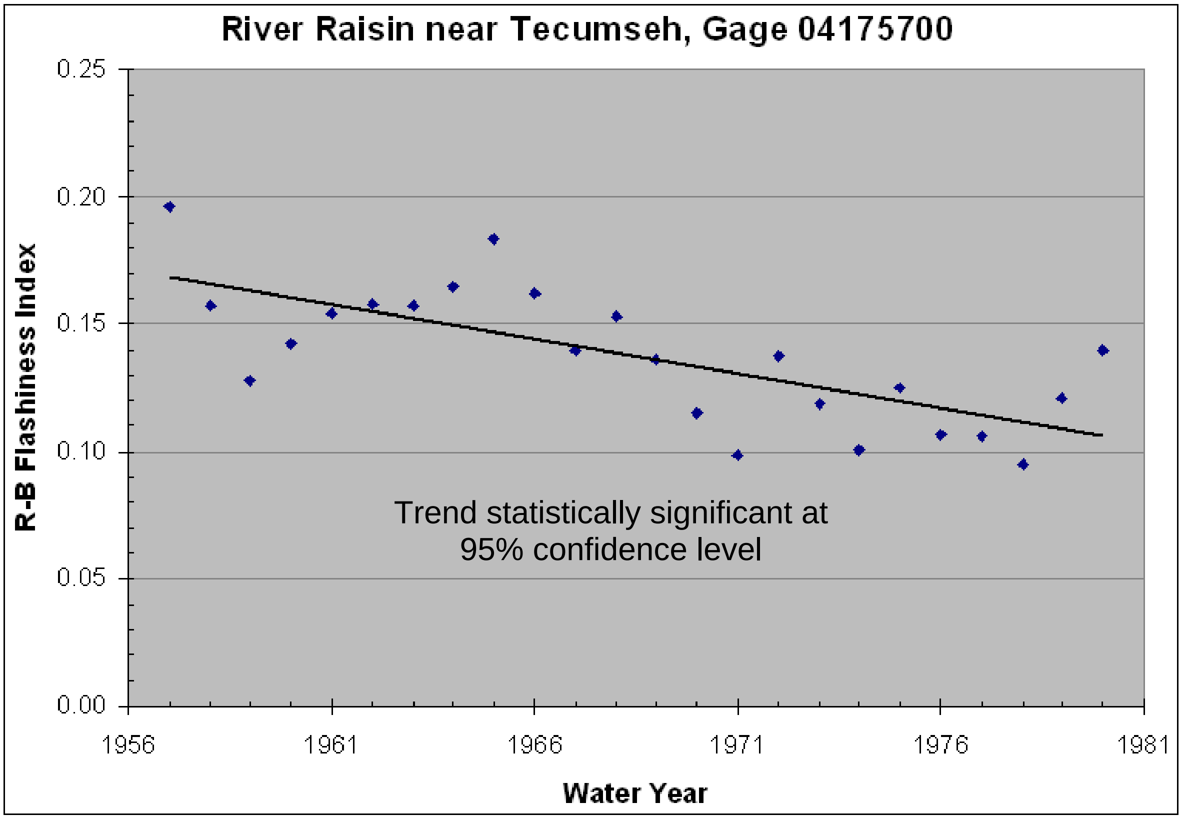

Figure 26: Richards-Baker Flashiness Analysis for Gage 04175700

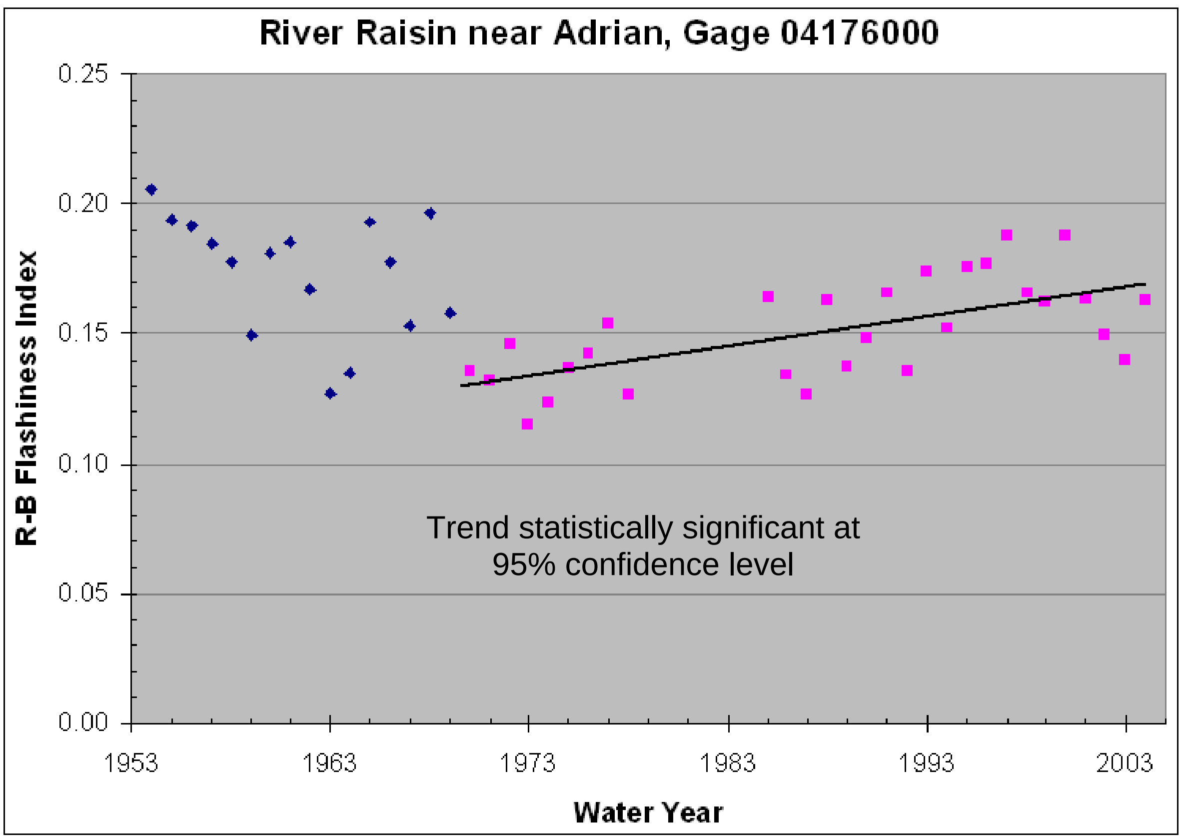

Figure 27: Richards-Baker Flashiness Analysis for Gage 04176000

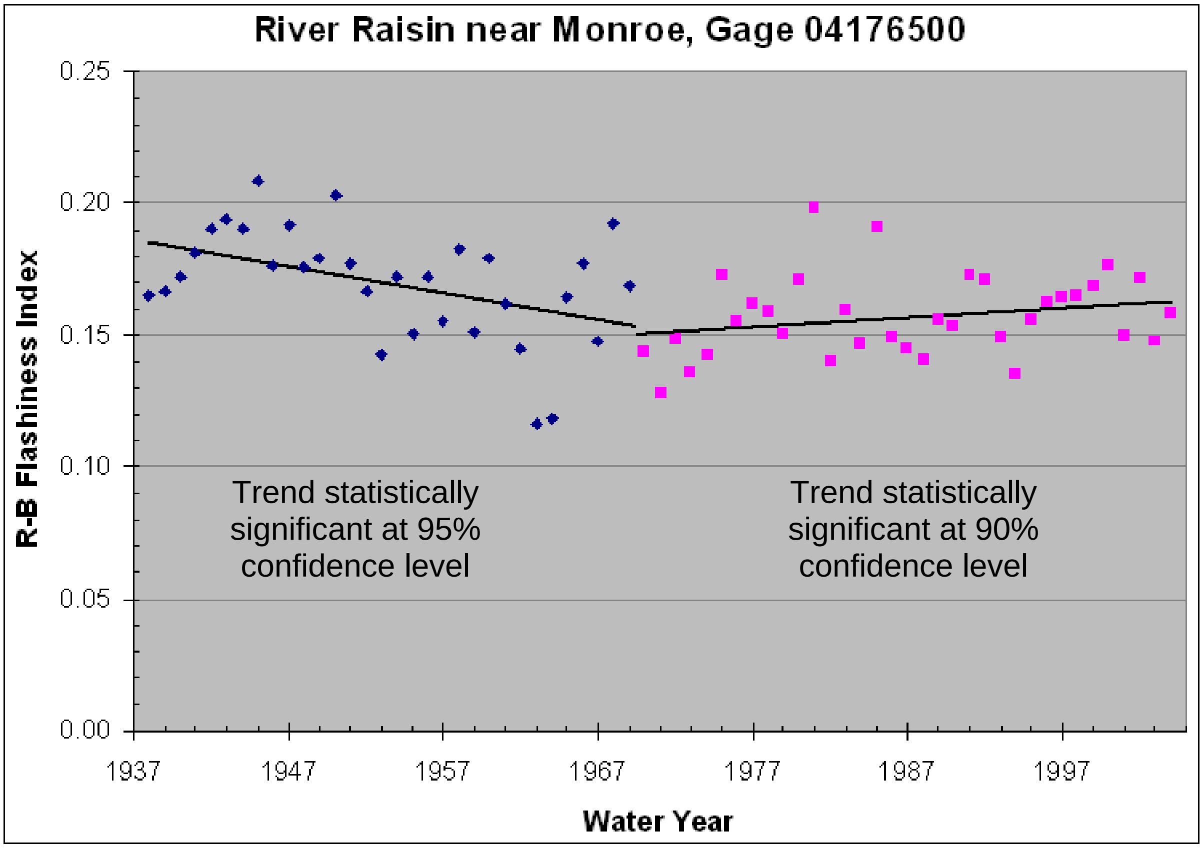

Figure 28: Richards-Baker Flashiness Analysis for Gage 04176500

Table 3: Summary of Flashiness Index Values

Gage ID	Description	Drainage Area (sq. mi.)	Water Years	Number of Years	Flashiness Index	Quartile Ranking	p-value*	Trend
04176400	Saline River near Saline	95	1966 - 1977	12	0.31	Lower middle		
04175600	River Raisin near Manchester	132	1970 - 2004	32	0.09	Lowest	0.530	No trend
04175700	River Raisin near Tecumseh	267	1957 - 1980	24	0.14	Lowest	0.000	Decrease
04176000	River Raisin near Adrian	463	1954 - 2004	45	0.16	Lower middle		
			1970 - 2004	29	0.15	Lower middle	0.000	Increase
04176500	River Raisin near Monroe	1042	1938 - 2004	67	0.16	Upper Middle		
			1938 - 1969	32	0.17	Upper middle	0.010	Decrease
			1970 - 2004	35	0.16	Upper middle	0.098	Increase

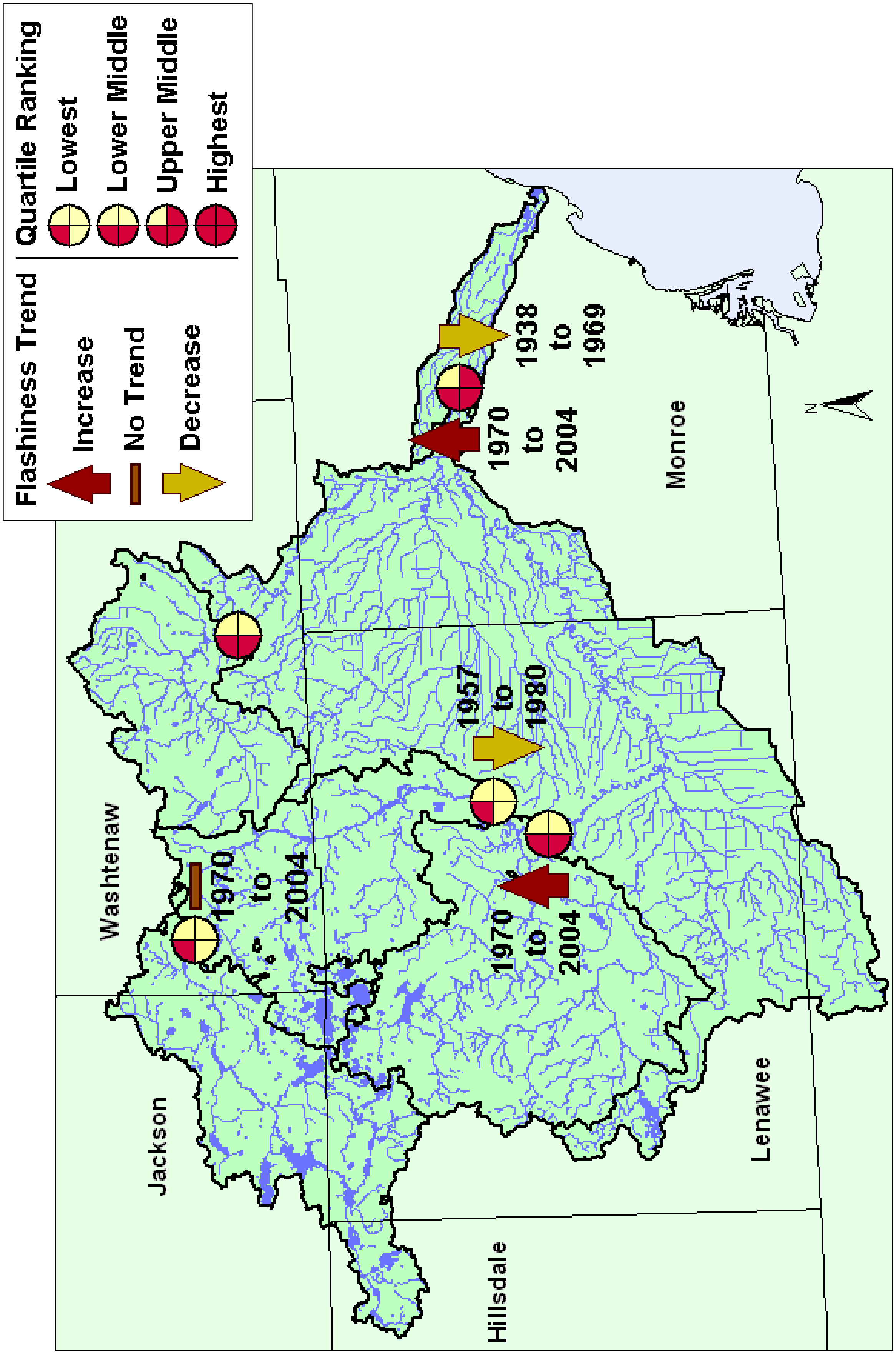

Figure 29: Richards-Baker Flashiness Analysis

Table 4: 1½ Year Peak Flows

Gage ID	Description	1½ Year Peak Flow (cfs)
04175600	River Raisin near Manchester	340
04175700	River Raisin near Tecumseh	1000
04176000	River Raisin near Adrian	2350
04176500	River Raisin near Monroe	5100

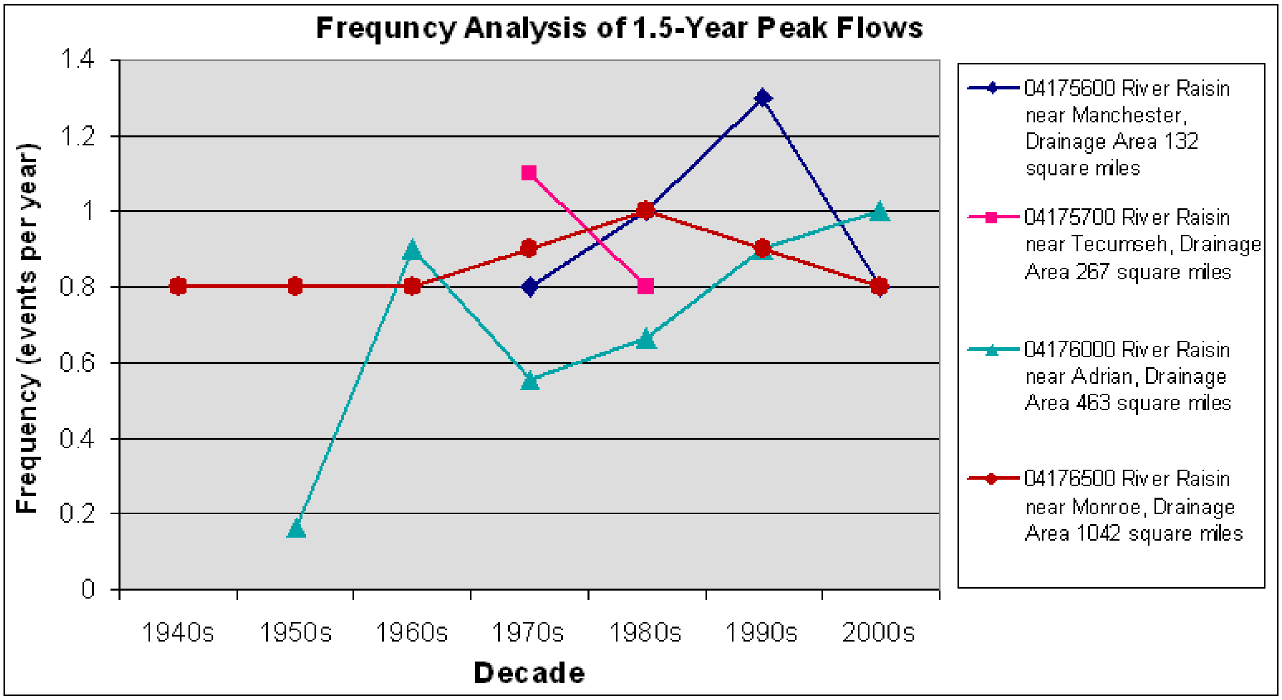

Figure 30: Exceedence of 1½ Year Peak Flows

Stream Order

Stream order is a numbering sequence which starts when two first order, or headwater, streams join, forming a second order stream, and so on. Two second order streams converging form a third order. Streams of lower order joining a higher order stream do not change the order of the higher, as shown in Figure 31. Stream order provides a comparison of the size and potential power of streams.

The Department of Natural Resources Institute for Fisheries Research and USGS Great Lakes Gap have nearly completed a three-year EPA-funded study that provides GIS stream order data for Michigan's streams using the 1:100,000 National Hydrography Dataset (NHD). The River Raisin results are shown in Figure 32.

The stream orders shown are not absolute. If larger scale maps are used or actual channels are found through field reconnaissance, the stream orders designated in Figure 32 may increase, because smaller channels are likely to be included. A more detailed analysis, based on 1:24,000 NHD layer, is also being developed.

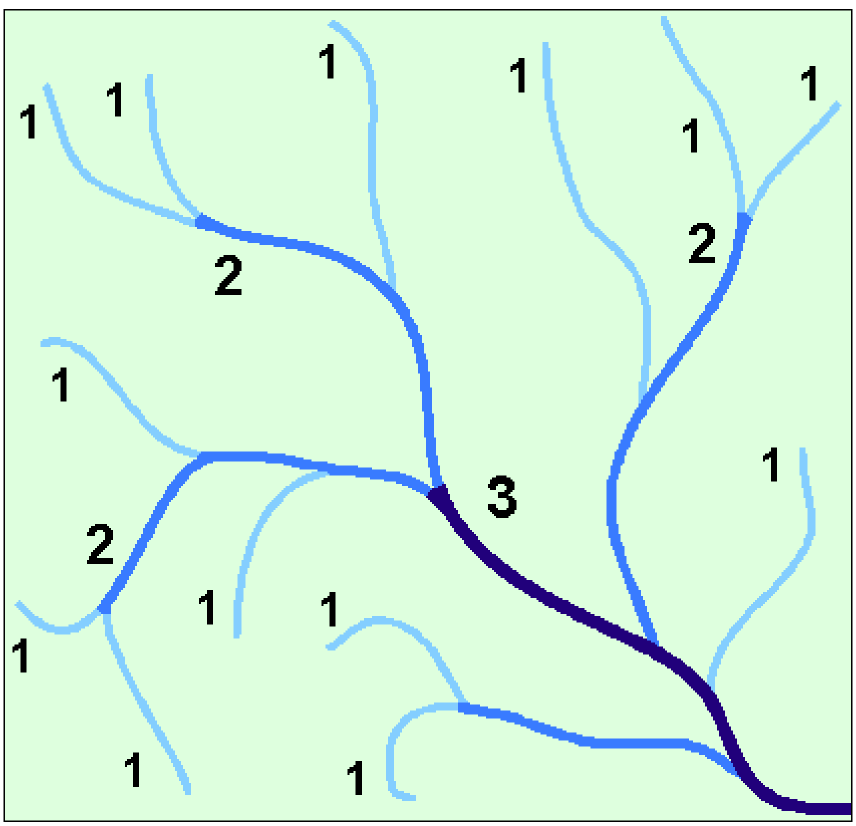

Figure 31: Stream Ordering Procedure

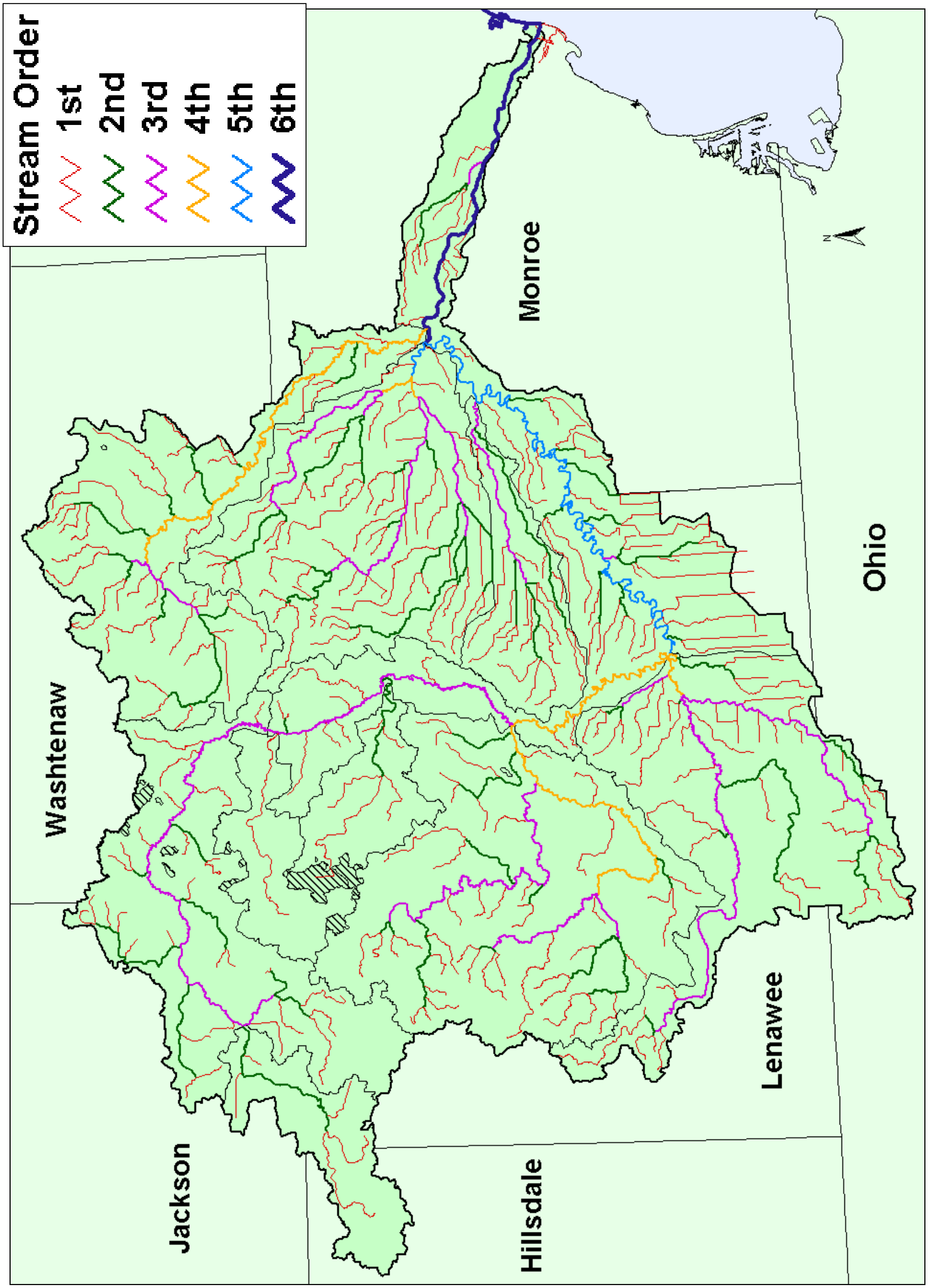

Figure 32: River Raisin Watershed Stream Orders

Recommendations

When precipitation falls, it can infiltrate into the ground, evapotranspirate back into the air, or run off the ground surface to a water body. It is helpful to consider three principal runoff effects: water quality, channel shape, and flood levels, as shown in Figure 33.

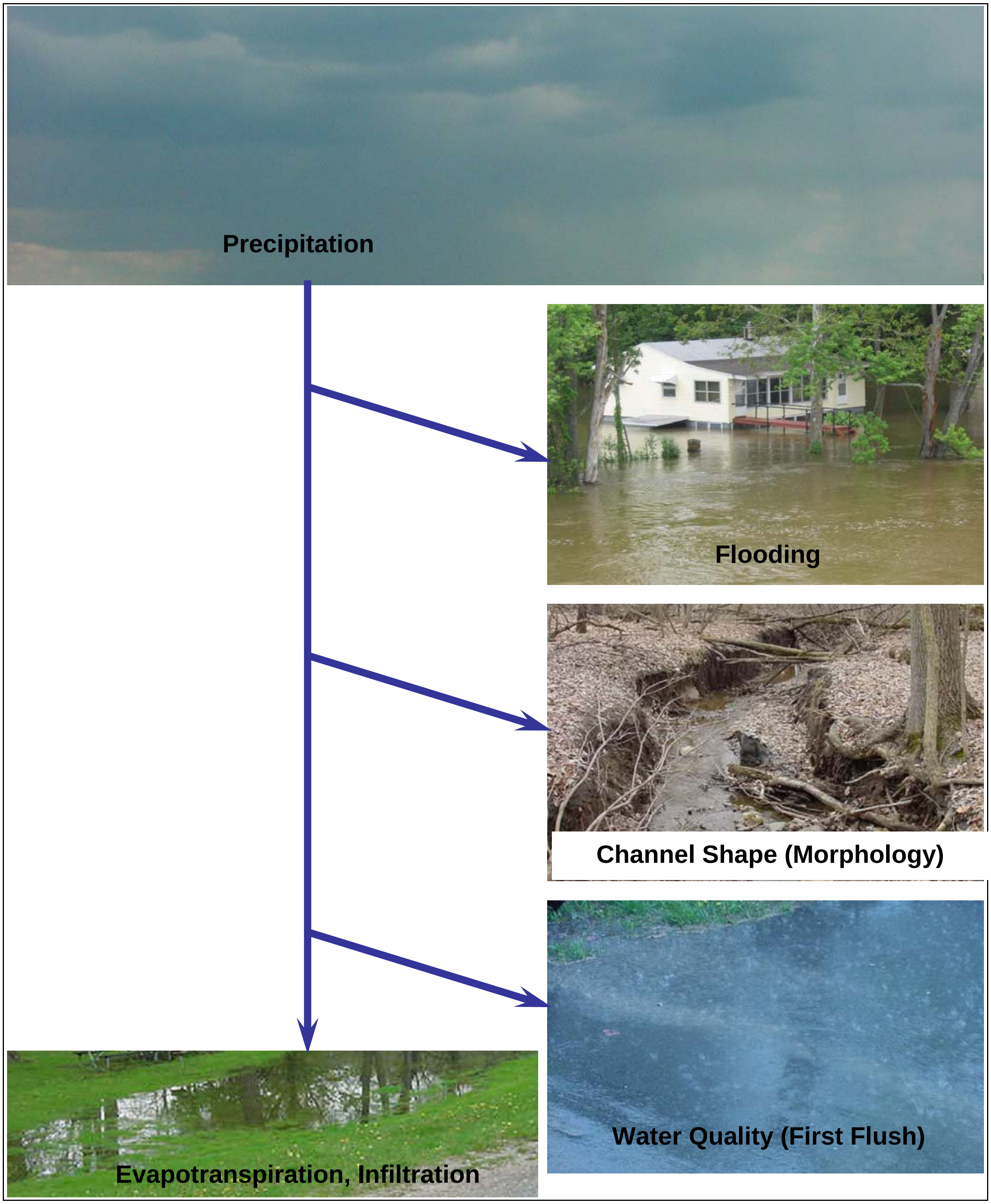

Figure 33: Runoff Impacts

Water Quality

Small runoff events and the first portion of the runoff from larger events typically pick up and deliver the majority of the pollutants to a watercourse in an urban area (Menerey, 1999 and Schueler, 2000). As the rain continues, there are fewer pollutants available to be carried by the runoff, and thus the pollutant concentration becomes lower. Figure 34 shows a typical plot of pollutant concentration versus time. The sharp rise in the plot has been termed the "first-flush." Some of the pollutants can settle out before discharging to a stream if this first flush runoff is detained for a period of time. Filtering systems are also used at some sites to treat the first flush stormwater.

Nationally, the amount of runoff recommended for capture and treatment varies from 0.5 inch per impervious acre to the runoff from a 50 percent chance storm. Michigan BMP guidelines recommend capture and treatment of 0.5 inch of runoff from a single site. The runoff is then released over 24 to 48 hours or is allowed to infiltrate into the ground within 72 hours. Dry detention ponds are less effective than retention or wet detention ponds, because the accumulated sediment in a dry detention pond may be easily resuspended by the next storm (Schueler, 2000).

First flush sizing criteria generally is only effective for a single site. Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet. For multiple sites or watershed wide design, it is best to design to capture and treat 90 percent of the runoff-producing storms. This "90 percent rule" effectively treats storm runoff that could be reaching the treatment at different times during the storm event. It was designed to provide the greatest amount of treatment that is economically feasible.

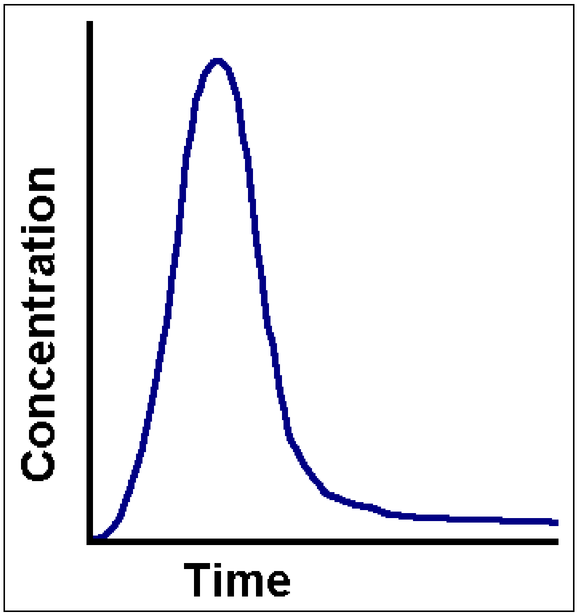

Figure 34: Plot of Pollutant Concentration versus Time

Stream Channel Protection

A stable stream is one that, over time, maintains a stable morphology: a constant pattern (sinuosity), slope, and cross-section, and neither aggrades or degrades. Stream stability is not the absence of erosion; some sediment movement and streambank erosion are natural.

Possible causes of erosion are:

- Natural river dynamics
- Sparse vegetative cover due to too much animal or human traffic
- Concentrated runoff adjacent to the streambank, i.e. gullies, seepage
- In-stream flow obstructions, i.e. log jams, failed bridge supports
- An infrequent event, such as an ice jam or low probability flood
- Unusually large or frequent wave action
- A significant change in the hydrologic characteristics (typically land use) of the watershed
- A change in the stream form impacting adjacent portions of the stream, i.e. dredging, channelization

An assessment of the cause(s) of erosion is necessary so that proposed solutions will be permanent and do not simply move the erosion problem to another location. The first six listed causes can produce localized erosion. Either of the last two causes, however, could produce a morphologically unstable stream. Symptoms of active channel enlargement in an unstable stream include:

- Knickpoint migration of the channel bottom
- Extensive and excessive erosion of the stream banks
- Erosion on the inside bank of channel bends
- Evidence in the streambanks of bed erosion down through an armor layer
- Exposed sanitary or storm sewers that were initially installed under the steam bed

Erosion in a morphologically unstable stream is caused by increases in the relatively frequent channel-forming flows that, because of their higher frequency, have more effect on channel form than extreme flood flows. As shown in Figure 35, multiplying the sediment transport rate curve (a) by the storm frequency of occurrence curve (b) yields a curve (c) that, at its peak, indicates the flow that moves most of the sediment in a stream. This flow is termed the effective discharge. The effective discharge usually has a one- to two-year recurrence interval and is the dominant channel-forming flow in a stable stream.

Increases in the frequency, duration, and magnitude of these flows causes stream bank and bed erosion as the stream adapts. According to the *Stream Corridor Restoration* manual, stream channels can often enlarge their cross-sectional area by a factor of 2 to 5 (FISRWG, 10/1998). In *Dynamics of Urban Stream Channel Enlargement, The Practice of Watershed Protection*, ultimate channel enlargement ratios of up to approximately 10 are reported, as shown in Figure 36 (Schueler and Holland, 2000). To prevent or minimize this erosion, watershed stakeholders should specifically consider stormwater management to protect channel morphology. Low impact development and infiltration BMPs can be incorporated to offset flow increases. Stormwater management ordinances can specifically address channel protection. However, where ordinances have included channel protection criteria, it has typically been focused on controlling peak flows from the 2-year storm. The nationally recognized Center for Watershed Protection asserts that 2-year peak discharge control doesn't work, because it does not reduce the frequency of erosive bankfull and sub-bankfull flows that often increase as development occurs within the watershed. Indeed, it may actually worsen conditions, since it increases the duration of these erosive, channel-forming flows. The Center for Watershed Protection suggests requiring 24-hour extended detention for runoff from 1-year storms as one option for protecting channel morphology. The intent is to limit detention pond outflows from these storms to non-erosive velocities, as shown in Figure 37. A few watershed plans funded through the MDEQ Nonpoint Source Program have recommended requirements based on this criterion. One example is shown in Figure 38. The MDEQ Nonpoint Source Program is currently exploring funding this analysis for all of Michigan. The results would be provided to the River Raisin stakeholders when available.

Control of channel-forming flows is not essential for some drainage areas. For example, detention designed to prevent streambank erosion may not be needed for runoff routed from a city through storm sewers to a large river, simply because the runoff routed through the storm sewers enters the river well ahead of the peak flow in the river. In this case, the city's management plan for stormwater routed through storm sewers should focus on treating the runoff to maintain water quality and providing sufficient drainage capacity to minimize flooding. Detention/retention might also be encouraged or required for other reasons, such as water quality improvement, groundwater replenishment, or if watershed planning indicates continued regional development would alter the river's flow regime or increase flood levels.

Hydrologic and hydraulic modeling may be justified to determine if runoff from a drainage area should be limited, either by detention or infiltration, to prevent flow or flood level increases or to verify that flood peaks are not increased due to the timing of the peak flows from detention ponds and in the stream. River Raisin stakeholders may elect to recommend some conditions when detention or retention for channel protection is not necessary. For example, the watershed stakeholders may adopt a watershed plan that calls for channel protection measures, unless runoff discharges from a storm sewer directly to a fourth order or higher stream, as shown in Figure 32.

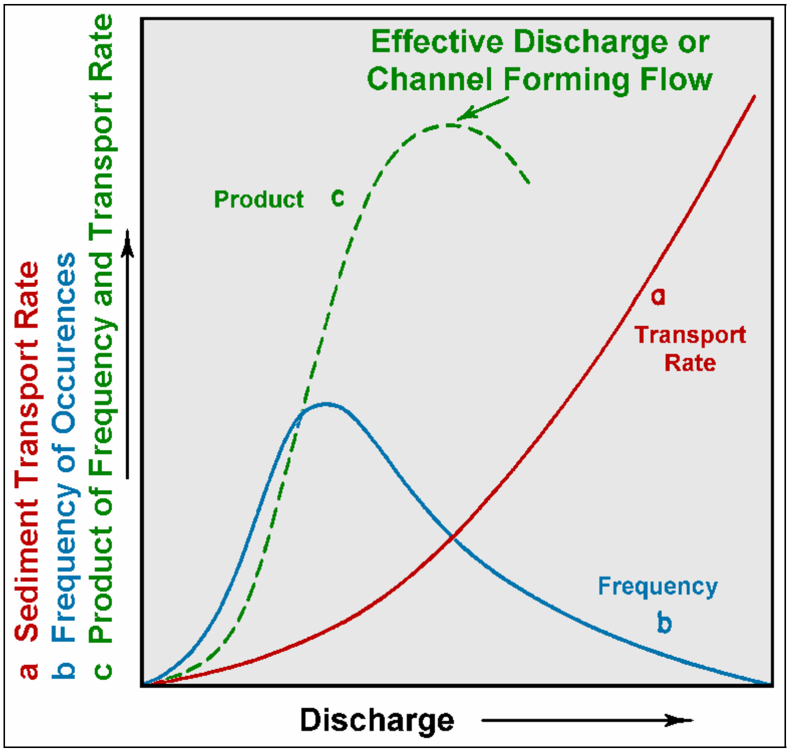

Figure 35: Effective Discharge (from *Applied River Morphology*. 1996. Dave Rosgen)

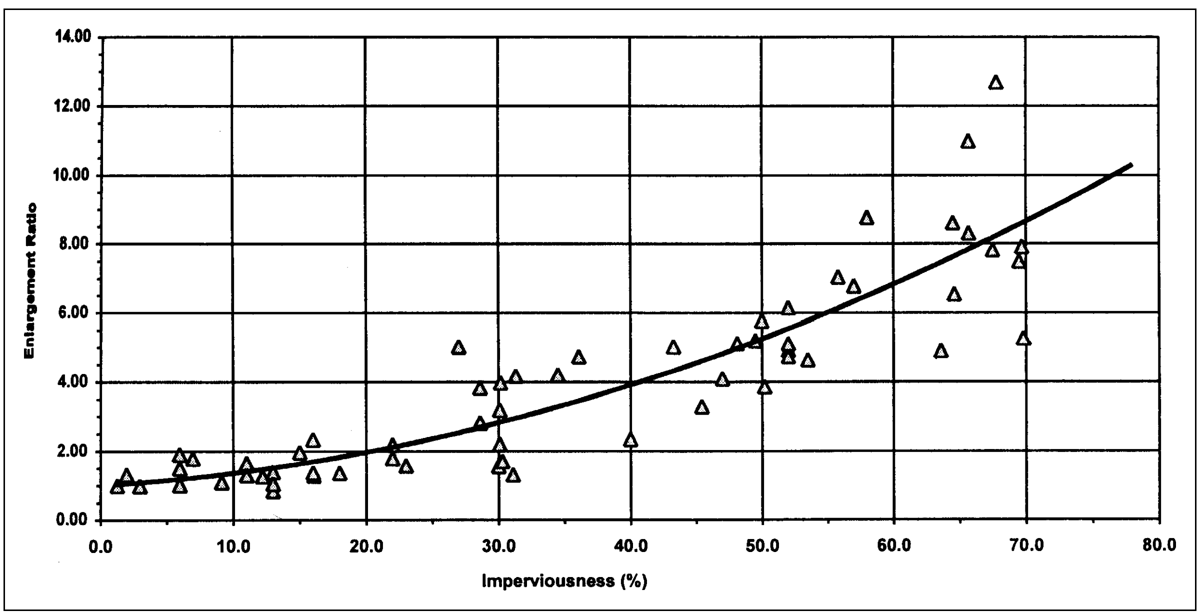

Figure 36: “Ultimate” Channel Enlargement as a Function of Impervious Cover in Alluvial Streams in Maryland, Vermont and Texas (MacRae and DeAndrea, 1999; and Brown and Claytor, 2000) (From *The Practice of Watershed Protection*, Thomas R. Schueler and Heather K. Holland, 2000)

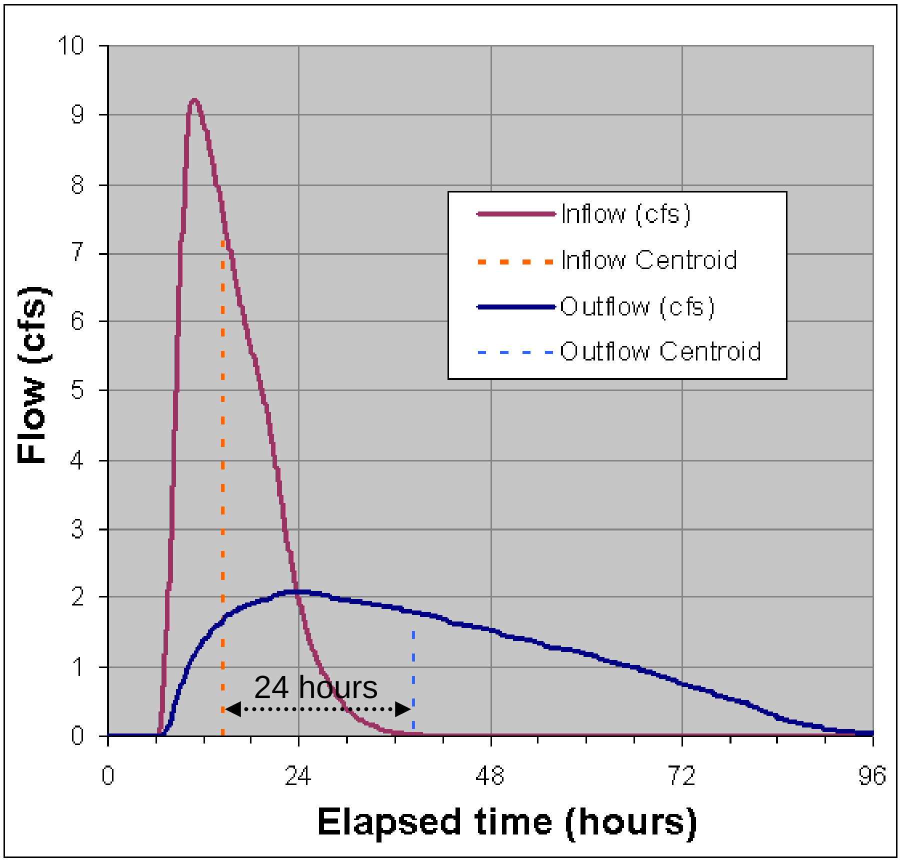

Figure 37: Example of 24-hour extended detention criterion applied to detention pond design

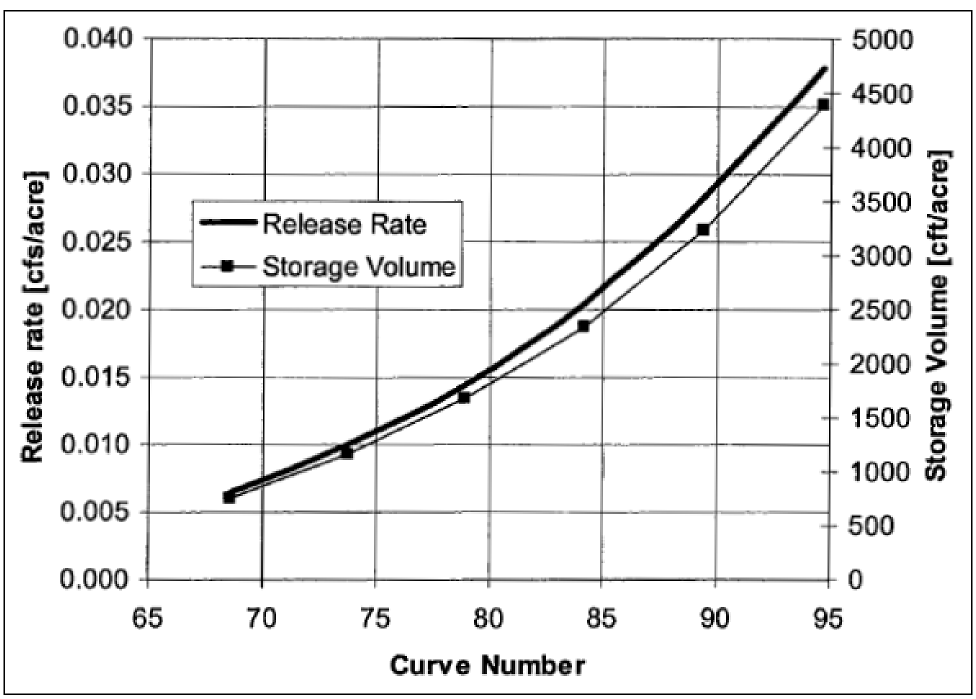

Figure 38: Example of detention pond requirements derived from the 24-hour extended detention criterion

Flood Protection

A river, stream, lake, or drain may occasionally overflow its banks and inundate adjacent land. This land is the floodplain. The floodplain refers to the land inundated by the 1 percent chance flood, commonly called the 100-year flood. Typically, a stable stream will recover naturally from these infrequent events. Developments should always include stormwater controls that prevent flood flows from exceeding pre-development conditions and putting people, homes, and other structures at risk. Many localities require new development to control the 4 percent chance flood, commonly called the 25-year flood, with some adding requirements to control the 1 percent chance flood.

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Appendix A: River Raisin Hydrologic Analysis Data

The following tables summarize the results of the hydrologic analysis by subbasin. These tables are likely to be most useful during the process for defining critical areas for the River Raisin Watershed Management Plan. Table A1 presents land use information. Table A2 provides runoff volumes per area. Table A3 lists yields per subbasin. Table A4 lists the imperviousness per subbasin. Table A5 lists Richards-Baker Flashiness Index Values for each water year.

Table A1: Land Use by Subbasins (Land use percentages that round to 0 are not listed)

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
Black 1	1800											2%		98%
	1978							95%				4%		
Black 2	1800											39%		61%
	1978	3%					1%	79%	2%		5%	8%		1%
Black 3	1800											40%		60%
	1978	2%						88%				9%		
Black 4	1800											2%		98%
	1978	1%						92%				7%		
Black 5	1800											55%		45%
	1978	1%						67%	4%	2%	7%	18%		1%
Black 6	1800													
	1978							94%				5%		
Black 7	1800													
	1978	4%	1%					90%		1%		3%		
Black 8	1800													
	1978	1%	1%					94%		1%		2%		
Black 9	1800													
	1978	2%						87%			1%	8%		2%
Black 10	1800											94%		6%
	1978	1%						84%		1%	2%	12%		
Black 11	1800											93%		7%
	1978							93%			1%	6%		
Black 12	1800													
	1978							91%			1%	8%		
Black 13	1800											82%		18%
	1978							88%				10%		
Black 14	1800											82%	1%	18%
	1978	1%						77%			8%	13%	1%	1%
Black 15	1800											88%	1%	12%
	1978							65%		1%	13%	11%	8%	2%
Black Creek	1800											62%		38%
	1978	1%						86%			2%	8%	1%	

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
Evans 1	1800											97%		3%
	1978	10%	3%		1%	2%	2%	68%		3%	1%	10%		
Evans 2	1800										41%	57%		2%
	1978	2%	2%					75%	1%	1%	5%	12%		1%
Evans 3	1800										56%	43%		1%
	1978	3%						77%			5%	13%		1%
Evans 4	1800											80%		20%
	1978	1%						85%		1%	1%	12%		
Evans 5	1800										83%	8%	1%	8%
	1978	4%					3%	53%		2%	12%	17%	1%	7%
Evans Creek	1800										32%	62%		6%
	1978	4%	1%				1%	72%		2%	4%	12%		1%
Goose 1	1800											75%	13%	12%
	1978	25%	1%					34%	3%		5%	13%	13%	6%
Goose 2	1800										2%	78%		20%
	1978	21%					1%	47%			2%	6%	16%	6%
Goose 3	1800											80%	4%	16%
	1978	7%	1%					51%			12%	12%	6%	10%
Goose 4	1800											79%	2%	19%
	1978	2%				1%	1%	41%		1%	12%	25%	5%	12%
Goose Creek	1800											78%	4%	17%
	1978	12%						44%	1%		9%	15%	9%	9%
Iron 1	1800										16%	80%		4%
	1978	2%				1%		62%	2%		17%	14%		2%
Iron 2	1800										54%	34%	2%	10%
	1978	2%						44%			19%	25%	4%	6%
Iron 3	1800											65%	18%	16%
	1978	9%	1%		1%		1%	25%		4%	9%	23%	19%	8%
Iron Creek	1800										22%	58%	9%	11%
	1978	5%						40%		2%	14%	21%	10%	6%
LitRR 1	1800											89%		11%
	1978							96%			1%	3%		
LitRR 2	1800											58%		42%
	1978							97%				2%		
LitRR 3	1800											54%		46%
	1978	1%						94%	1%		1%	3%		
LitRR 4	1800											82%		18%
	1978							97%				3%		
LitRR 5	1800											96%		4%
	1978							91%		1%	1%	6%		
Little River Raisin	1800											76%		24%
	1978							95%			1%	3%		
LowRR 1	1800											57%	6%	37%
	1978	25%	8%	6%	6%		2%	34%			4%	7%	7%	2%
LowRR 2	1800										25%	59%		17%
	1978	14%	4%	6%	1%		1%	60%			3%	7%	4%	1%

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
LowRR 3	1800										22%	46%	5%	27%
	1978	9%	1%			3%		78%				4%	4%	1%
LowRR 4	1800										36%	52%		12%
	1978	2%						87%			2%	9%		
LowRR 5	1800										22%	69%	4%	6%
	1978	5%						80%			1%	9%	4%	1%
LowRR 6	1800										35%	62%	3%	
	1978	12%	2%		2%		2%	74%			1%	8%		
LowRR 7	1800										29%	57%	1%	14%
	1978	3%	1%		1%		2%	81%			2%	10%		
LowRR 8	1800										26%	57%	1%	15%
	1978	6%						81%			1%	11%		
LowRR 9	1800										4%	21%		76%
	1978	1%						91%	1%	1%	2%	4%		
LowRR 10	1800											93%	7%	
	1978	1%						87%	1%			11%		
LowRR 11	1800											94%		6%
	1978	1%						97%				1%		
LowRR 12	1800											13%		87%
	1978							97%				2%		
LowRR 13	1800											90%	2%	8%
	1978	3%						90%		1%		5%		
LowRR 14	1800											31%		69%
	1978	1%		1%				95%				1%		
LowRR 15	1800											52%	2%	47%
	1978	3%						92%				3%		
LowRR 16	1800											20%	1%	79%
	1978							98%				2%		1%
LowRR 17	1800											37%	8%	55%
	1978	2%						73%		3%	1%	19%		1%
LowRR 18	1800											82%	5%	13%
	1978	4%	1%			2%		64%			3%	26%		
LowRR 19	1800											71%	4%	24%
	1978	6%	1%	3%		1%		52%		1%	5%	28%		2%
LowRR 20	1800											90%	1%	8%
	1978	11%	2%	3%	1%	7%	2%	54%		1%	4%	14%	2%	
LowRR 21	1800											91%	1%	7%
	1978	9%			1%		3%	65%	1%	1%	6%	11%	2%	2%
LowRR 22	1800											93%	1%	6%
	1978	5%	1%	2%		3%		73%		1%	4%	9%		
LowRR 23	1800											65%	24%	10%
	1978	6%	2%		1%		2%	66%		2%	8%	9%	2%	2%
Lower River Raisin	1800										10%	62%	2%	26%
	1978	5%	1%	1%	1%	1%	1%	78%			2%	9%	1%	1%
Macon 1	1800											99%		1%
	1978	5%	2%	1%	1%	12%	1%	69%			1%	7%	1%	

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
Macon 2	1800											42%		58%
	1978	1%	1%		2%	4%		86%				5%	1%	
Macon 3	1800											43%		57%
	1978	2%	1%	1%	1%			89%		1%	1%	3%		
Macon 4	1800											94%		6%
	1978	1%						84%		1%	5%	8%		
Macon 5	1800											21%		79%
	1978	1%			1%			96%				2%		
Macon 6	1800											17%		83%
	1978	1%						95%		1%	1%	2%		
Macon 7	1800											24%		76%
	1978							96%				3%		
Macon 8	1800											89%		11%
	1978				1%			94%			1%	3%		
Macon 9	1800											49%		51%
	1978	1%						94%			1%	4%		
Macon 10	1800											16%		84%
	1978	1%						93%	2%	1%	1%	3%		
Macon 11	1800											77%		23%
	1978				1%		1%	89%			2%	8%		
Macon 12	1800											80%		20%
	1978	2%	1%					95%				1%		
Macon 13	1800													100%
	1978	1%						97%			1%	2%		
Macon 14	1800											44%		56%
	1978	1%						94%		1%	3%	2%		
Macon 15	1800											91%		9%
	1978	2%						80%		1%	2%	14%		
Macon 16	1800											87%		13%
	1978	2%	1%					70%		1%	4%	20%		
Macon Creek	1800											54%		46%
	1978	1%						90%			2%	5%		
Saline 1	1800										9%	54%		36%
	1978	3%			1%		1%	77%		1%	2%	14%		2%
Saline 2	1800											88%		12%
	1978	12%	2%	1%	3%		1%	69%			2%	11%		
Saline 3	1800											66%		34%
	1978	7%						69%			6%	16%	1%	
Saline 4	1800											96%		4%
	1978	6%	5%		1%			58%		1%	19%	10%		
Saline 5	1800											89%		11%
	1978	4%			1%			68%			8%	19%		1%
Saline 6	1800											81%		19%
	1978	12%	3%				3%	49%			15%	17%	1%	
Saline 7	1800											90%		10%
	1978	10%	1%	1%				57%		1%	17%	9%		3%

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
Saline 8	1800											75%		25%
	1978	6%	1%	2%	2%		4%	46%		1%	23%	13%		1%
Saline 9	1800											70%	1%	29%
	1978	3%						77%			8%	12%	1%	
Saline 10	1800											85%		15%
	1978	4%						73%			8%	12%	1%	2%
Saline 11	1800											85%		15%
	1978	2%				1%		75%			11%	10%		
Saline 12	1800											63%	1%	36%
	1978	1%					1%	78%			7%	12%	1%	
Saline 13	1800											78%		22%
	1978	1%	1%					85%			5%	8%		1%
Saline 14	1800										2%	87%	2%	10%
	1978	3%						61%		1%	14%	19%	1%	1%
Saline River	1800										1%	77%		21%
	1978	5%	1%		1%		1%	67%			11%	13%		1%
SBrRR 1	1800											84%	1%	15%
	1978	11%	8%	4%	2%		10%	39%		1%	3%	22%		1%
SBrRR 2	1800											87%		13%
	1978	14%		3%			2%	65%	1%	2%	5%	8%		
SBrRR 3	1800											82%		18%
	1978	5%					2%	74%		3%	4%	11%		
SBrRR 4	1800											97%		3%
	1978	39%	15%	4%	3%		3%	28%		1%	3%	3%		
SBrRR 5	1800											95%		5%
	1978	9%	1%			1%	2%	66%		2%	6%	10%	1%	1%
SBrRR 6	1800											91%		9%
	1978							83%		2%	3%	11%		1%
SBrRR 7	1800										8%	76%		16%
	1978							82%		2%	3%	13%		1%
SBrRR 8	1800										29%	53%		18%
	1978	1%	9%					70%			5%	13%		1%
SBrRR 9	1800										3%	78%	2%	17%
	1978	4%					1%	55%			13%	13%	4%	10%
SBrRR 10	1800											83%		17%
	1978	2%						66%	1%	2%	8%	17%		4%
SBrRR 11	1800											72%	15%	13%
	1978	14%				1%	1%	28%		2%	10%	18%	17%	8%
SBrRR 12	1800											96%		4%
	1978	6%	2%	5%	2%	1%		63%		3%	3%	12%	2%	1%
SBrRR 13	1800											85%		15%
	1978					1%		71%		1%	1%	24%		2%
SBrRR 14	1800											64%		35%
	1978							85%		1%	1%	10%		1%
SBrRR 15	1800											73%		27%
	1978	1%						78%		6%	2%	10%		3%

Description	Scenario	Residential	Institutional	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
SBrRR 16	1800											82%		18%
	1978	2%						79%		2%	3%	14%		1%
SBrRR 17	1800											93%		7%
	1978							74%		2%	6%	17%		2%
SBrRR 18	1800											98%		2%
	1978	1%						72%		3%	10%	12%		1%
SBrRR 19	1800											91%		9%
	1978	1%						82%		1%	3%	12%		
SBrRR 20	1800											84%		16%
	1978						1%	78%		2%	2%	15%		1%
South Branch River Raisin	1800										2%	84%		13%
	1978	4%	1%	1%			1%	69%		2%	5%	13%	1%	2%
UppRR 1	1800											89%		11%
	1978	3%						58%			24%	14%		
UppRR 2	1800										3%	89%	1%	7%
	1978	3%						58%	1%		18%	17%	1%	1%
UppRR 3	1800										58%	31%		11%
	1978	9%	1%				1%	50%			17%	13%	3%	5%
UppRR 4	1800										20%	64%		16%
	1978	3%	1%					52%			21%	16%	1%	6%
UppRR 5	1800											89%		11%
	1978	1%						47%			23%	24%	1%	3%
UppRR 6	1800											81%		19%
	1978	4%						49%			8%	35%		3%
UppRR 7	1800											79%	2%	19%
	1978	6%						38%		2%	13%	27%	3%	11%
UppRR 8	1800											72%	2%	26%
	1978	5%						43%			13%	27%	2%	9%
UppRR 9	1800											73%	1%	26%
	1978	15%				2%		34%			11%	24%	7%	7%
UppRR 10	1800											84%		16%
	1978	10%	1%			1%	1%	58%			2%	15%		11%
UppRR 11	1800											73%	9%	18%
	1978	9%	3%				2%	48%			1%	20%	6%	10%
UppRR 12	1800											69%	8%	23%
	1978	17%	2%	1%		1%	2%	33%			5%	19%	9%	12%
UppRR 13	1800											71%	3%	26%
	1978	3%				1%	6%	38%		1%	13%	18%	5%	15%
UppRR 14	1800											77%	2%	21%
	1978	2%				2%	2%	43%	1%	1%	13%	23%	4%	10%
Upper River Raisin	1800										4%	75%	2%	18%
	1978	6%	1%			1%	1%	47%			13%	20%	3%	8%
Entire Watershed	1800										4%	70%	1%	25%
	1978	4%	1%				1%	72%		1%	6%	11%	1%	2%

Table A2: Runoff volumes per area per subbasin

Subbasin			Runoff Volume/Area		
ID	Description	Area (sq. mi.)	1800 (inches)	1978 (inches)	Change
Black01	Black Creek at mouth	13.3	*0.63	0.83	*31%
Black02	Big Meadow Drain at Gorman Road, #04176110	12.6	0.40	0.44	10%
Black03	Black Creek at confluence with Bear Creek	13.6	0.58	0.80	37%
Black04	Bear Creek at mouth	7.8	0.63	0.86	36%
Black05	Gleason Brook at mouth	5.0	0.43	0.51	19%
Black06	Bear Creek at confluence with unnamed tributary	9.0	**	0.90	**
Black07	Bear Creek at confluence with Little Bear Creek	6.3	**	0.80	**
Black08	Little Bear Creek at mouth	4.9	**	0.80	**
Black09	Bear Creek at confluence with unnamed tributary	11.4	**	0.64	**
Black10	Black Creek at confluence with Nile Ditch	13.5	0.55	0.91	66%
Black11	Nile Ditch at mouth	11.5	0.63	0.97	54%
Black12	Nile Ditch at M-52	13.1	**	0.86	**
Black13	Black Creek at confluence with unnamed tributary	12.2	0.40	0.75	90%
Black14	Bear Creek at Whaley Highway	6.0	0.48	0.75	58%
Black15	Bear Creek at Lake Hudson Dam # 467	10.5	0.50	0.81	61%
Evans01	Evans Creek at mouth	7.5	0.33	0.65	101%
Evans02	Evans Creek at Taylor/Lamkin	8.6	0.38	0.75	95%
Evans03	Taylor Creek at mouth	4.5	0.41	0.74	80%
Evans04	Lamkin Drain at mouth	4.8	0.51	0.82	61%
Evans05	Evans Creek at Wyman Road	4.0	0.19	0.45	136%
Goose01	Goose Creek at mouth	7.0	0.28	0.49	76%
Goose02	Goose Creek at Lake Columbia Outlet	8.0	0.29	0.63	116%
Goose03	Goose Creek at Little Goose Lake outlet	13.3	0.26	0.50	97%
Goose04	Goose Creek at US-12	11.8	0.25	0.39	59%
Iron01	Iron Creek at mouth	7.1	0.26	0.51	98%
Iron02	Iron Creek at Henzie Road	10.4	0.23	0.43	83%
Iron03	Iron Creek at Noggles Road	14.2	0.41	0.59	44%
LitRR01	Little River Raisin at mouth	9.7	0.29	0.60	110%
LitRR02	Swamp Raisin Creek at mouth	5.4	0.50	0.65	30%
LitRR03	Swamp Raisin Creek downstream of Schwab Drain	11.4	0.49	0.70	41%
LitRR04	Swamp Raisin Creek at Fry Drain/Garno Road	7.1	0.30	0.64	111%
LitRR05	Swamp Raisin Creek at Grosvenor Highway	9.2	0.33	0.61	89%
LowRR01	River Raisin at mouth	7.5	0.46	0.80	74%
LowRR02	Mason Run at I-75	7.2	0.32	0.66	106%
LowRR03	River Raisin at confluence with Willow Run	3.4	0.40	0.73	81%

Subbasin			Runoff Volume/Area		
ID	Description	Area (sq. mi.)	1800 (inches)	1978 (inches)	Change
LowRR04	Willow Run at mouth	11.0	0.37	0.61	65%
LowRR05	River Raisin at Gage #04176500	4.9	0.37	0.65	76%
LowRR06	River Raisin at confluence with Macon Creek	5.0	0.26	0.58	127%
LowRR07	River Raisin at confluence with Little River Raisin	14.2	0.19	0.47	155%
LowRR08	Camp Drain at mouth	11.0	0.22	0.45	99%
LowRR09	Burton and White Drain at mouth	4.2	0.49	0.54	10%
LowRR10	River Raisin at confluence with Camp Drain	4.4	0.45	0.58	31%
LowRR11	Camp Drain at mouth	8.0	0.29	0.56	94%
LowRR12	Kellar Drain at mouth	4.3	0.62	0.87	41%
LowRR13	River Raisin at confluence with Floodwood Creek	11.5	0.23	0.56	144%
LowRR14	Floodwood Creek at mouth	13.9	0.62	0.88	43%
LowRR15	River Raisin at US-223	14.1	0.57	0.78	37%
LowRR16	Bay Drain at mouth	5.1	0.61	0.86	41%
LowRR17	River Raisin at confluence with Black Creek	6.2	0.51	0.55	7%
LowRR18	River Raisin at Deerfield Road	4.4	0.34	0.44	32%
LowRR19	River Raisin at confluence with South Branch	6.3	0.23	0.40	73%
LowRR20	River Raisin at confluence with unnamed tributary	7.3	0.31	0.46	50%
LowRR21	River Raisin at confluence with Evans Creek	11.4	0.37	0.69	85%
LowRR22	River Raisin at Newburg Road	5.5	0.34	0.60	75%
LowRR23	River Raisin at downstream of island near Clinton	10.4	0.31	0.65	107%
Macon01	Macon Creek at mouth	4.0	0.21	0.77	259%
Macon02	Macon Creek at confluence with North Branch	3.6	0.49	0.71	44%
Macon03	North Branch Macon Creek at confluence with Bear Swamp Creek	8.9	0.53	0.74	40%
Macon04	North Branch Macon Creek at Hack Road	14.9	0.42	0.74	77%
Macon05	Bear Swamp Creek at mouth	8.4	0.61	0.83	34%
Macon06	Bear Swamp Creek at Petersburg Road	11.2	0.64	0.92	44%
Macon07	Macon Creek at confluence with South Branch	15.2	0.63	0.82	29%
Macon08	South Branch Macon Creek at mouth	7.7	0.51	0.83	64%
Macon09	South Branch Macon Creek at County Line Highway	7.1	0.52	0.76	47%
Macon10	Holloway, Wilson, Sutton Drains at confluence with South Branch Macon Creek	7.1	0.56	0.72	30%
Macon11	South Branch Macon Creek at Schreeder Brook	10.8	0.49	0.75	53%
Macon12	Schreeder Brook at mouth	10.1	0.56	0.81	44%
Macon13	Richardson Drain at mouth	6.6	0.64	0.92	45%
Macon14	Macon Creek upstream of Richardson	11.6	0.60	0.88	46%

Subbasin			Runoff Volume/Area		
ID	Description	Area (sq. mi.)	1800 (inches)	1978 (inches)	Change
	Drain				
Macon15	Macon Creek at Britton Highway	7.3	0.46	0.75	62%
Macon16	Macon Creek at Clinton Macon Road	7.1	0.51	0.79	57%
Saline01	Saline River at mouth	14.3	0.27	0.45	67%
Saline02	Saline River at Allison Road	3.5	0.13	0.43	238%
Saline03	Saline River at Wabash Road	10.2	0.42	0.65	55%
Saline04	Saline River at confluence with outlet from Ella Lee Lake	7.0	0.19	0.40	107%
Saline05	Saline River at gage 04176400 and Maple Road	4.0	0.33	0.61	86%
Saline06	Saline River at Koch Warner Drain	3.3	0.41	0.63	56%
Saline07	Koch Warner Drain at mouth	12.1	0.37	0.61	68%
Saline08	Wood Outlet Drain at mouth	15.2	0.38	0.56	49%
Saline09	Saline River at confluence with unnamed tributary	4.5	0.45	0.69	52%
Saline10	Unnamed tributary to Saline River at mouth	13.5	0.39	0.69	78%
Saline11	Saline River at Austin Road	13.5	0.43	0.69	58%
Saline12	Saline River at Feldkamp Road	12.4	0.44	0.61	38%
Saline13	Unnamed tributary to Saline River at mouth	6.0	0.49	0.79	62%
Saline14	Saline River at Burmeister Road	9.8	0.37	0.62	66%
SBrRR01	South Branch River Raisin at mouth	3.7	0.40	0.63	57%
SBrRR02	Cook Drain at mouth	7.8	0.21	0.46	114%
SBrRR03	Beaver Creek at mouth	14.5	0.41	0.67	66%
SBrRR04	South Branch River Raisin at confluence with Wolf Creek	5.8	0.26	0.73	181%
SBrRR05	Wolf Creek at mouth	15.1	0.39	0.69	79%
SBrRR06	Wolf Creek at confluence with Black Creek	11.3	0.43	0.77	78%
SBrRR07	Black Creek at mouth	8.9	0.49	0.78	59%
SBrRR08	Black Creek at Shepherd Road	7.0	0.41	0.76	85%
SBrRR09	Wolf Creek at confluence with Squaw Creek	15.0	0.36	0.61	67%
SBrRR10	Squaw Creek at mouth	11.4	0.36	0.62	69%
SBrRR11	Wolf Creek at Cambridge Lake outlet	3.7	0.40	0.55	38%
SBrRR12	South Branch River Raisin at US 223	14.5	0.29	0.65	125%
SBrRR13	South Branch River Raisin at confluence with Stony Creek	6.6	0.32	0.57	80%
SBrRR14	Stony Creek at mouth	13.7	0.48	0.72	51%
SBrRR15	South Branch River Raisin at confluence with Hazen Creek	4.4	0.46	0.76	64%
SBrRR16	Hazen Creek at mouth	4.7	0.42	0.74	77%
SBrRR17	Hazen Creek at confluence with Stoddard Drain	8.5	0.41	0.72	75%
SBrRR18	Stoddard Drain at mouth	11.9	0.40	0.71	78%
SBrRR19	South Branch River Raisin at confluence with Harrison Drain	13.0	0.45	0.79	73%
SBrRR20	Harrison Drain at mouth	8.0	0.48	0.80	69%

Subbasin			Runoff Volume/Area		
ID	Description	Area (sq. mi.)	1800 (inches)	1978 (inches)	Change
UppRR01	River Raisin at Allen Road	6.2	0.32	0.57	78%
UppRR02	River Raisin at confluence with unnamed tributary	10.0	0.32	0.54	72%
UppRR03	River Raisin at Ford Manchester Dam #391 Austin Road	5.0	0.18	0.39	122%
UppRR04	River Raisin at Manchester Mill Dam #715	11.3	0.17	0.38	116%
UppRR05	River Raisin at Gage #04175600	10.5	0.16	0.31	98%
UppRR06	River Raisin at confluence with Manchester Drain	3.7	0.23	0.39	73%
UppRR07	Manchester Drain at mouth	11.1	0.22	0.39	73%
UppRR08	Unnamed tributary to River Raisin at mouth	13.5	0.15	0.26	71%
UppRR09	River Raisin at confluence with unnamed tributary	3.2	0.27	0.40	50%
UppRR10	River Raisin at Austin Road	12.6	0.18	0.46	152%
UppRR11	River Raisin Tributary at Stony Lake Outlet	6.0	0.29	0.53	84%
UppRR12	River Raisin at confluence with Goose Creek	11.1	0.32	0.49	55%
UppRR13	River Raisin at confluence with unnamed tributary	12.5	0.30	0.42	38%
UppRR14	River Raisin at Pickerel Lake outlet	7.4	0.27	0.41	52%

* calculated runoff curve number does not include Ohio, which represents 1.5 percent of the subbasin
** 1800 land cover data not available for Ohio, runoff curve number not calculated

Table A3: Yields per subbasin

Subbasin		1800 Yield			1978 Yield			Yield Change
ID	Area (sq. mi.)	Minimum	Calculated	Maximum	Minimum	Calculated	Maximum	
Black 1	13.3	*0.008	*0.007	*0.007	0.028	0.024	0.023	*248%
Black 2	12.6	0.009	0.008	0.008	0.022	0.019	0.019	133%
Black 3	13.6	0.007	0.006	0.006	0.022	0.019	0.019	207%
Black 4	7.8	0.007	0.006	0.006	0.024	0.022	0.021	261%
Black 5	5.0	0.012	0.011	0.010	0.025	0.024	0.021	119%
Black 6	9.0	**	**	**	0.048	0.043	0.040	**
Black 7	6.3	**	**	**	0.021	0.019	0.018	**
Black 8	4.9	**	**	**	0.032	0.031	0.027	**
Black 9	11.4	**	**	**	0.024	0.021	0.021	**
Black 10	13.5	0.011	0.010	0.010	0.027	0.023	0.023	135%
Black 11	11.5	0.015	0.013	0.013	0.038	0.033	0.032	153%
Black 12	13.1	**	**	**	0.042	0.036	0.035	**
Black 13	12.2	0.007	0.006	0.006	0.022	0.019	0.019	229%
Black 14	6.0	0.014	0.013	0.012	0.035	0.033	0.030	146%
Black 15	10.5	0.016	0.014	0.014	0.028	0.025	0.024	72%
Evans 1	7.5	0.010	0.009	0.008	0.027	0.024	0.022	172%
Evans 2	8.6	0.018	0.016	0.015	0.042	0.038	0.035	129%
Evans 3	4.5	0.026	0.026	0.022	0.049	0.048	0.042	86%
Evans 4	4.8	0.014	0.013	0.012	0.040	0.038	0.034	186%
Evans 5	4.0	0.007	0.006	0.006	0.017	0.016	0.014	158%
Goose 1	7.0	0.008	0.007	0.006	0.015	0.014	0.013	100%
Goose 2	8.0	0.017	0.015	0.014	0.044	0.039	0.037	159%

Subbasin		1800 Yield			1978 Yield			Yield Change
ID	Area (sq. mi.)	Minimum	Calculated	Maximum	Minimum	Calculated	Maximum	
Goose 3	13.3	0.010	0.009	0.009	0.023	0.019	0.019	123%
Goose 4	11.8	0.008	0.007	0.007	0.014	0.012	0.011	72%
Iron 1	7.1	0.012	0.011	0.010	0.030	0.028	0.025	151%
Iron 2	10.4	0.008	0.007	0.007	0.015	0.013	0.013	95%
Iron 3	14.2	0.012	0.010	0.010	0.019	0.016	0.016	57%
LitRR 1	9.7	0.002	0.002	0.002	0.009	0.008	0.007	267%
LitRR 2	5.4	0.006	0.006	0.005	0.018	0.017	0.015	186%
LitRR 3	11.4	0.010	0.009	0.009	0.032	0.028	0.027	219%
LitRR 4	7.1	0.008	0.007	0.007	0.031	0.029	0.026	304%
LitRR 5	9.2	0.012	0.011	0.010	0.035	0.031	0.030	191%
LowRR 1	7.5	0.005	0.004	0.004	0.011	0.010	0.009	132%
LowRR 2	7.2	0.003	0.003	0.003	0.008	0.007	0.006	148%
LowRR 3	3.4	0.007	0.007	0.006	0.019	0.019	0.016	150%
LowRR 4	11.0	0.006	0.006	0.005	0.019	0.017	0.016	195%
LowRR 5	4.9	0.007	0.006	0.006	0.013	0.013	0.011	100%
LowRR 6	5.0	0.005	0.005	0.004	0.016	0.016	0.014	227%
LowRR 7	14.2	0.001	0.001	0.001	0.006	0.005	0.005	316%
LowRR 8	11.0	0.002	0.002	0.001	0.007	0.006	0.006	268%
LowRR 9	4.2	0.008	0.008	0.007	0.023	0.022	0.019	178%
LowRR 10	4.4	0.004	0.004	0.004	0.009	0.008	0.007	110%
LowRR 11	8.0	0.005	0.005	0.004	0.016	0.014	0.013	212%
LowRR 12	4.3	0.008	0.007	0.006	0.028	0.027	0.024	266%
LowRR 13	11.5	0.004	0.003	0.003	0.017	0.015	0.015	329%
LowRR 14	13.9	0.008	0.007	0.007	0.027	0.023	0.023	250%
LowRR 15	14.1	0.007	0.006	0.006	0.021	0.018	0.018	210%
LowRR 16	5.1	0.010	0.009	0.008	0.031	0.030	0.026	214%
LowRR 17	6.2	0.003	0.002	0.002	0.006	0.005	0.005	121%
LowRR 18	4.4	0.005	0.005	0.005	0.013	0.013	0.011	146%
LowRR 19	6.3	0.003	0.003	0.003	0.008	0.008	0.007	173%
LowRR 20	7.3	0.011	0.010	0.009	0.022	0.020	0.018	105%
LowRR 21	11.4	0.014	0.012	0.012	0.031	0.027	0.026	121%
LowRR 22	5.5	0.016	0.015	0.014	0.044	0.041	0.037	172%
LowRR 23	10.4	0.013	0.012	0.011	0.036	0.031	0.030	170%
Macon 1	4.0	0.009	0.009	0.008	0.039	0.038	0.033	308%
Macon 2	3.6	0.013	0.013	0.011	0.039	0.038	0.033	205%
Macon 3	8.9	0.006	0.006	0.005	0.021	0.019	0.018	228%
Macon 4	14.9	0.011	0.009	0.009	0.027	0.023	0.023	154%
Macon 5	8.4	0.009	0.008	0.007	0.030	0.027	0.025	240%
Macon 6	11.2	0.010	0.009	0.009	0.038	0.033	0.032	271%
Macon 7	15.2	0.010	0.008	0.008	0.031	0.026	0.026	223%
Macon 8	7.7	0.010	0.009	0.008	0.025	0.023	0.021	159%
Macon 9	7.1	0.009	0.008	0.008	0.029	0.026	0.024	220%
Macon 10	7.1	0.008	0.008	0.007	0.027	0.025	0.023	233%
Macon 11	10.8	0.009	0.008	0.007	0.027	0.023	0.023	201%
Macon 12	10.1	0.013	0.012	0.011	0.037	0.033	0.031	177%
Macon 13	6.6	0.012	0.011	0.010	0.048	0.044	0.040	296%
Macon 14	11.6	0.007	0.006	0.006	0.026	0.022	0.022	244%
Macon 15	7.3	0.015	0.014	0.013	0.040	0.037	0.034	161%
Macon 16	7.1	0.014	0.013	0.012	0.036	0.033	0.031	152%
Saline 1	14.3	0.003	0.002	0.002	0.007	0.006	0.006	181%
Saline 2	3.5	0.002	0.002	0.002	0.011	0.011	0.010	505%
Saline 3	10.2	0.005	0.005	0.005	0.015	0.014	0.013	180%
Saline 4	7.0	0.007	0.007	0.006	0.022	0.020	0.018	196%
Saline 5	4.0	0.014	0.013	0.011	0.042	0.041	0.036	212%

Subbasin		1800 Yield			1978 Yield			Yield Change
ID	Area (sq. mi.)	Minimum	Calculated	Maximum	Minimum	Calculated	Maximum	
Saline 6	3.3	0.016	0.016	0.014	0.043	0.043	0.036	163%
Saline 7	12.1	0.010	0.009	0.008	0.021	0.018	0.017	105%
Saline 8	15.2	0.012	0.010	0.010	0.029	0.024	0.024	141%
Saline 9	4.5	0.016	0.016	0.014	0.047	0.045	0.039	185%
Saline 10	13.5	0.012	0.010	0.010	0.030	0.025	0.025	151%
Saline 11	13.5	0.013	0.011	0.011	0.032	0.027	0.027	153%
Saline 12	12.4	0.010	0.009	0.009	0.026	0.022	0.022	147%
Saline 13	6.0	0.014	0.013	0.012	0.041	0.038	0.035	185%
Saline 14	9.8	0.014	0.012	0.012	0.031	0.028	0.026	130%
SBrRR 1	3.7	0.011	0.011	0.010	0.029	0.028	0.024	154%
SBrRR 2	7.8	0.005	0.005	0.004	0.018	0.017	0.016	246%
SBrRR 3	14.5	0.010	0.008	0.008	0.026	0.022	0.022	174%
SBrRR 4	5.8	0.008	0.007	0.007	0.029	0.027	0.025	276%
SBrRR 5	15.1	0.010	0.008	0.008	0.021	0.018	0.018	114%
SBrRR 6	11.3	0.007	0.006	0.006	0.017	0.015	0.014	150%
SBrRR 7	8.9	0.010	0.009	0.009	0.025	0.023	0.021	150%
SBrRR 8	7.0	0.012	0.011	0.010	0.035	0.032	0.030	195%
SBrRR 9	15.0	0.013	0.011	0.011	0.024	0.020	0.020	83%
SBrRR 10	11.4	0.011	0.010	0.009	0.024	0.021	0.020	117%
SBrRR 11	3.7	0.014	0.013	0.012	0.020	0.020	0.017	49%
SBrRR 12	14.5	0.010	0.008	0.008	0.025	0.021	0.021	152%
SBrRR 13	6.6	0.006	0.006	0.005	0.016	0.015	0.013	157%
SBrRR 14	13.7	0.009	0.008	0.008	0.024	0.020	0.020	157%
SBrRR 15	4.4	0.015	0.014	0.012	0.035	0.034	0.030	143%
SBrRR 16	4.7	0.012	0.011	0.010	0.033	0.031	0.027	181%
SBrRR 17	8.5	0.011	0.010	0.009	0.026	0.023	0.022	131%
SBrRR 18	11.9	0.015	0.013	0.013	0.030	0.026	0.026	101%
SBrRR 19	13.0	0.010	0.009	0.008	0.026	0.022	0.022	161%
SBrRR 20	8.0	0.015	0.014	0.013	0.040	0.036	0.034	164%
UppRR 1	6.2	0.007	0.007	0.006	0.020	0.019	0.017	179%
UppRR 2	10.0	0.013	0.011	0.011	0.030	0.026	0.025	138%
UppRR 3	5.0	0.008	0.008	0.007	0.022	0.021	0.018	174%
UppRR 4	11.3	0.005	0.004	0.004	0.011	0.010	0.010	152%
UppRR 5	10.5	0.005	0.004	0.004	0.011	0.010	0.009	135%
UppRR 6	3.7	0.006	0.005	0.005	0.013	0.013	0.011	135%
UppRR 7	11.1	0.005	0.005	0.005	0.010	0.009	0.009	88%
UppRR 8	13.5	0.003	0.003	0.003	0.006	0.005	0.005	103%
UppRR 9	3.2	0.007	0.007	0.006	0.013	0.013	0.011	79%
UppRR 10	12.6	0.003	0.002	0.002	0.007	0.006	0.006	165%
UppRR 11	6.0	0.008	0.008	0.007	0.017	0.016	0.015	115%
UppRR 12	11.1	0.006	0.005	0.005	0.011	0.009	0.009	74%
UppRR 13	12.5	0.005	0.004	0.004	0.008	0.007	0.007	50%
UppRR 14	7.4	0.010	0.009	0.008	0.017	0.016	0.015	75%

* calculated yields do not include Ohio, which represents 1.5 percent of the subbasin
** 1800 land cover data not available for Ohio, yields not calculated

Table A4: Imperviousness per subbasin

Subbasin ID	Description	Area (sq. mi.)	Imperviousness (percent)
Black 1	Black Creek at mouth	13.3	1
Black 2	Big Meadow Drain at Gorman Road, #04176110	12.6	2
Black 3	Black Creek at confluence with Bear Creek	13.6	1

Subbasin ID	Description	Area (sq. mi.)	Imperviousness (percent)
Black 4	Bear Creek at mouth	7.8	1
Black 5	Gleason Brook at mouth	5.0	1
Black 6	Bear Creek at confluence with unnamed tributary	9.0	1
Black 7	Bear Creek at confluence with Little Bear Creek	6.3	3
Black 8	Little Bear Creek at mouth	4.9	2
Black 9	Bear Creek at confluence with unnamed tributary	11.4	1
Black 10	Black Creek at confluence with Nile Ditch	13.5	1
Black 11	Nile Ditch at mouth	11.5	1
Black 12	Nile Ditch at M-52	13.1	1
Black 13	Black Creek at confluence with unnamed tributary	12.2	1
Black 14	Bear Creek at Whaley Highway	6.0	1
Black 15	Bear Creek at Lake Hudson Dam # 467	10.5	1
Evans 1	Evans Creek at mouth	7.5	9
Evans 2	Evans Creek at Taylor/Lamkin	8.6	3
Evans 3	Taylor Creek at mouth	4.5	2
Evans 4	Lamkin Drain at mouth	4.8	1
Evans 5	Evans Creek at Wyman Road	4.0	2
Goose 1	Goose Creek at mouth	7.0	10
Goose 2	Goose Creek at Lake Columbia Outlet	8.0	8
Goose 3	Goose Creek at Little Goose Lake outlet	13.3	3
Goose 4	Goose Creek at US-12	11.8	1
Iron 1	Iron Creek at mouth	7.1	1
Iron 2	Iron Creek at Henzie Road	10.4	1
Iron 3	Iron Creek at Noggles Road	14.2	4
LitRR 1	Little River Raisin at mouth	9.7	1
LitRR 2	Swamp Raisin Creek at mouth	5.4	1
LitRR 3	Swamp Raisin Creek downstream of Schwab Drain	11.4	1
LitRR 4	Swamp Raisin Creek at Fry Drain/Garno Road	7.1	1
LitRR 5	Swamp Raisin Creek at Grosvenor Highway	9.2	1
LowRR 1	River Raisin at mouth	7.5	31
LowRR 2	Mason Run at I-75	7.2	16
LowRR 3	River Raisin at confluence with Willow Run	3.4	4
LowRR 4	Willow Run at mouth	11.0	1
LowRR 5	River Raisin at Gage #04176500	4.9	2
LowRR 6	River Raisin at confluence with Macon Creek	5.0	10
LowRR 7	River Raisin at confluence with Little River Raisin	14.2	3
LowRR 8	Camp Drain at mouth	11.0	4
LowRR 9	Burton and White Drain at mouth	4.2	1
LowRR 10	River Raisin at confluence with Camp Drain	4.4	1
LowRR 11	Camp Drain at mouth	8.0	2
LowRR 12	Kellar Drain at mouth	4.3	1
LowRR 13	River Raisin at confluence with Floodwood Creek	11.5	3
LowRR 14	Floodwood Creek at mouth	13.9	2
LowRR 15	River Raisin at US-223	14.1	3
LowRR 16	Bay Drain at mouth	5.1	1
LowRR 17	River Raisin at confluence with Black Creek	6.2	2
LowRR 18	River Raisin at Deerfield Road	4.4	3
LowRR 19	River Raisin at confluence with South Branch	6.3	5
LowRR 20	River Raisin at confluence with unnamed tributary	7.3	10
LowRR 21	River Raisin at confluence with Evans Creek	11.4	6

Subbasin ID	Description	Area (sq. mi.)	Imperviousness (percent)
LowRR 22	River Raisin at Newburg Road	5.5	4
LowRR 23	River Raisin at downstream of island near Clinton	10.4	6
Macon 1	Macon Creek at mouth	4.0	7
Macon 2	Macon Creek at confluence with North Branch	3.6	4
Macon 3	North Branch Macon Creek at confluence with Bear Swamp Creek	8.9	4
Macon 4	North Branch Macon Creek at Hack Road	14.9	1
Macon 5	Bear Swamp Creek at mouth	8.4	2
Macon 6	Bear Swamp Creek at Petersburg Road	11.2	1
Macon 7	Macon Creek at confluence with South Branch	15.2	1
Macon 8	South Branch Macon Creek at mouth	7.7	2
Macon 9	South Branch Macon Creek at County Line Highway	7.1	1
Macon 10	Holloway, Wilson, Sutton Drains at confluence with South Branch Macon Creek	7.1	1
Macon 11	South Branch Macon Creek at Schreeder Brook	10.8	2
Macon 12	Schreeder Brook at mouth	10.1	2
Macon 13	Richardson Drain at mouth	6.6	1
Macon 14	Macon Creek upstream of Richardson Drain	11.6	1
Macon 15	Macon Creek at Britton Highway	7.3	2
Macon 16	Macon Creek at Clinton Macon Road	7.1	2
Saline 1	Saline River at mouth	14.3	2
Saline 2	Saline River at Allison Road	3.5	10
Saline 3	Saline River at Wabash Road	10.2	4
Saline 4	Saline River at confluence with outlet from Ella Lee Lake	7.0	7
Saline 5	Saline River at gage 04176400 and Maple Road	4.0	3
Saline 6	Saline River at Koch Warner Drain	3.3	10
Saline 7	Koch Warner Drain at mouth	12.1	7
Saline 8	Wood Outlet Drain at mouth	15.2	7
Saline 9	Saline River at confluence with unnamed tributary	4.5	1
Saline 10	Unnamed tributary to Saline River at mouth	13.5	2
Saline 11	Saline River at Austin Road	13.5	1
Saline 12	Saline River at Feldkamp Road	12.4	1
Saline 13	Unnamed tributary to Saline River at mouth	6.0	2
Saline 14	Saline River at Burmeister Road	9.8	1
SBrRR 1	South Branch River Raisin at mouth	3.7	18
SBrRR 2	Cook Drain at mouth	7.8	8
SBrRR 3	Beaver Creek at mouth	14.5	3
SBrRR 4	South Branch River Raisin at confluence with Wolf Creek	5.8	43
SBrRR 5	Wolf Creek at mouth	15.1	6
SBrRR 6	Wolf Creek at confluence with Black Creek	11.3	1
SBrRR 7	Black Creek at mouth	8.9	1
SBrRR 8	Black Creek at Shepherd Road	7.0	9
SBrRR 9	Wolf Creek at confluence with Squaw Creek	15.0	2
SBrRR 10	Squaw Creek at mouth	11.4	2
SBrRR 11	Wolf Creek at Cambridge Lake outlet	3.7	4
SBrRR 12	South Branch River Raisin at US 223	14.5	10
SBrRR 13	South Branch River Raisin at confluence with Stony Creek	6.6	1
SBrRR 14	Stony Creek at mouth	13.7	1
SBrRR 15	South Branch River Raisin at confluence with Hazen Creek	4.4	1
SBrRR 16	Hazen Creek at mouth	4.7	1

Subbasin ID	Description	Area (sq. mi.)	Imperviousness (percent)
SBrRR 17	Hazen Creek at confluence with Stoddard Drain	8.5	1
SBrRR 18	Stoddard Drain at mouth	11.9	2
SBrRR 19	South Branch River Raisin at confluence with Harrison Drain	13.0	1
SBrRR 20	Harrison Drain at mouth	8.0	1
UppRR 1	River Raisin at Allen Road	6.2	1
UppRR 2	River Raisin at confluence with unnamed tributary	10.0	2
UppRR 3	River Raisin at Ford Manchester Dam #391 Austin Road	5.0	4
UppRR 4	River Raisin at Manchester Mill Dam #715	11.3	3
UppRR 5	River Raisin at Gage #04175600	10.5	1
UppRR 6	River Raisin at confluence with Manchester Drain	3.7	2
UppRR 7	Manchester Drain at mouth	11.1	2
UppRR 8	Unnamed tributary to River Raisin at mouth	13.5	2
UppRR 9	River Raisin at confluence with unnamed tributary	3.2	4
UppRR 10	River Raisin at Austin Road	12.6	4
UppRR 11	River Raisin Tributary at Stony Lake Outlet	6.0	6
UppRR 12	River Raisin at confluence with Goose Creek	11.1	7
UppRR 13	River Raisin at confluence with unnamed tributary	12.5	1
UppRR 14	River Raisin at Pickerel Lake outlet	7.4	1

Table A5: Richards-Baker Flashiness Index Yearly Values

Year	Richards-Baker Flashiness Index Yearly Values				
	04176400, Saline River near Saline, Drainage Area 95 Sq. Mi.	04175600, River Raisin near Manchester, Drainage Area 132 Square Miles	04175700, River Raisin near Tecumseh, Drainage Area 267 Sq. Mi.	04176000, River Raisin near Adrian, Drainage Area 463 Sq. Mi.	04176500, River Raisin near Monroe, Drainage Area 1042 Sq. Mi.
1938					0.165
1939					0.167
1940					0.172
1941					0.181
1942					0.190
1943					0.194
1944					0.191
1945					0.209
1946					0.177
1947					0.192
1948					0.176
1949					0.179
1950					0.203
1951					0.177
1952					0.167
1953					0.143
1954				0.206	0.172
1955				0.194	0.151
1956				0.192	0.173
1957			0.196	0.185	0.156

Year	Richards-Baker Flashiness Index Yearly Values				
	04176400, Saline River near Saline, Drainage Area 95 Sq. Mi.	04175600, River Raisin near Manchester, Drainage Area 132 Square Miles	04175700, River Raisin near Tecumseh, Drainage Area 267 Sq. Mi.	04176000, River Raisin near Adrian, Drainage Area 463 Sq. Mi.	04176500, River Raisin near Monroe, Drainage Area 1042 Sq. Mi.
1958			0.157	0.178	0.183
1959			0.128	0.150	0.151
1960			0.143	0.181	0.179
1961			0.155	0.186	0.162
1962			0.158	0.167	0.145
1963			0.157	0.127	0.116
1964			0.165	0.135	0.119
1965			0.184	0.193	0.165
1966	0.351		0.162	0.178	0.177
1967	0.277		0.140	0.153	0.148
1968	0.468		0.153	0.197	0.193
1969	0.308		0.136	0.158	0.168
1970	0.269	0.106	0.115	0.135	0.143
1971	0.217	0.100	0.099	0.132	0.128
1972	0.330	0.105	0.137	0.146	0.148
1973	0.330	0.074	0.119	0.115	0.136
1974	0.279	0.071	0.101	0.124	0.143
1975	0.336	0.090	0.125	0.137	0.173
1976	0.274	0.074	0.107	0.143	0.155
1977	0.254	0.121	0.106	0.154	0.162
1978		0.077	0.095	0.126	0.159
1979		0.094	0.121		0.151
1980		0.095	0.139		0.171
1981		0.083			0.198
1982					0.140
1983					0.159
1984					0.147
1985		0.105		0.164	0.191
1986		0.099		0.134	0.149
1987		0.078		0.126	0.145
1988		0.090		0.163	0.141
1989		0.101		0.138	0.156
1990		0.094		0.148	0.153
1991		0.094		0.166	0.173
1992		0.084		0.135	0.171
1993		0.076		0.174	0.149
1994		0.095		0.153	0.135
1995		0.105		0.176	0.156
1996		0.093		0.177	0.162
1997		0.090		0.188	0.164
1998		0.088		0.166	0.165
1999		0.096		0.162	0.169

Year	Richards-Baker Flashiness Index Yearly Values				
	04176400, Saline River near Saline, Drainage Area 95 Sq. Mi.	04175600, River Raisin near Manchester, Drainage Area 132 Square Miles	04175700, River Raisin near Tecumseh, Drainage Area 267 Sq. Mi.	04176000, River Raisin near Adrian, Drainage Area 463 Sq. Mi.	04176500, River Raisin near Monroe, Drainage Area 1042 Sq. Mi.
2000		0.114		0.189	0.176
2001		0.090		0.164	0.150
2002		0.086		0.150	0.172
2003		0.100		0.140	0.148
2004		0.101		0.163	0.158
Average	0.308	0.093	0.137	0.159	0.163

Appendix B: River Raisin Hydrologic Parameters

The watershed was modeled using HEC-HMS 2.2.2 to calculate surface runoff volumes and peak flows from individual subbasins. This appendix is provided so that the model may be recreated. Table B1 provides the parameters that were specified for each of the hydrologic elements. In HEC-HMS, the percent impervious fields were left at 0.0, because it is already incorporated in the curve numbers. The initial loss field fields were left blank so that HEC-HMS uses the default equation based on the curve number. Peak flows calculated with HEC-HMS were multiplied by the ponding adjustment factors listed in Table B2 to incorporate flow attenuation by storage in the subbasin. HEC-HMS was run for a seven-day duration using a one-minute computation interval.

Table B1: Subbasin Parameters – Drainage Area, Curve Number, and Time of Concentration

Subbasins		Drainage Area (sq. mi.)	Runoff Curve Number		
ID	Description		1800	1978	Tc
Black 1	Black Creek at mouth	13.28	*77.9	82.0	21.39
Black 2	Big Meadow Drain at Gorman Road, #04176110	12.58	71.8	73.1	10.69
Black 3	Black Creek at confluence with Bear Creek	13.59	76.7	81.5	24.41
Black 4	Bear Creek at mouth	7.77	77.9	82.6	24.17
Black 5	Gleason Brook at mouth	4.97	72.7	74.9	8.40
Black 6	Bear Creek at confluence with unnamed tributary	8.99	**	83.4	11.71
Black 7	Bear Creek at confluence with Little Bear Creek	6.32	**	81.5	23.59
Black 8	Little Bear Creek at mouth	4.90	**	81.6	14.19
Black 9	Bear Creek at confluence with unnamed tributary	11.44	**	78.2	13.37
Black 10	Black Creek at confluence with Nile Ditch	13.45	75.9	83.6	22.18
Black 11	Nile Ditch at mouth	11.47	77.8	84.6	17.67
Black 12	Nile Ditch at M-52	13.08	**	82.7	12.80
Black 13	Black Creek at confluence with unnamed tributary	12.17	71.6	80.6	22.35
Black 14	Bear Creek at Whaley Highway	6.00	73.9	80.6	9.63
Black 15	Bear Creek at Lake Hudson Dam # 467	10.47	74.7	81.8	10.40
Evans 1	Evans Creek at mouth	7.48	69.3	78.5	13.91
Evans 2	Evans Creek at Taylor/Lamkin	8.55	71.2	80.5	8.16
Evans 3	Taylor Creek at mouth	4.47	72.1	80.3	5.98
Evans 4	Lamkin Drain at mouth	4.80	74.9	82.0	10.44
Evans 5	Evans Creek at Wyman Road	3.95	64.0	73.3	7.84
Goose 1	Goose Creek at mouth	7.04	67.7	74.8	10.16
Goose 2	Goose Creek at Lake Columbia Outlet	7.97	68.2	78.2	3.32
Goose 3	Goose Creek at Little Goose Lake outlet	13.30	66.8	74.8	6.52
Goose 4	Goose Creek at US-12	11.83	66.4	71.5	8.70
Iron 1	Iron Creek at mouth	7.12	66.8	74.8	6.47
Iron 2	Iron Creek at Henzie Road	10.42	65.8	72.5	8.97
Iron 3	Iron Creek at Noggles Road	14.16	72.0	77.0	9.47
LitRR 1	Little River Raisin at mouth	9.74	68.0	77.3	51.24
LitRR 2	Swamp Raisin Creek at mouth	5.41	74.5	78.2	23.05
LitRR 3	Swamp Raisin Creek downstream of Schwab Drain	11.38	74.4	79.3	14.11
LitRR 4	Swamp Raisin Creek at Fry Drain/Garno Road	7.06	68.5	78.0	12.21
LitRR 5	Swamp Raisin Creek at Grosvenor Highway	9.21	69.3	77.5	10.33

	Subbasins	Drainage Area	Runoff Curve Number		
ID	Description	(sq. mi.)	1800	1978	Tc
LowRR 1	River Raisin at mouth	7.51	73.5	81.8	30.77
LowRR 2	Mason Run at I-75	7.23	69.2	78.8	39.67
LowRR 3	River Raisin at confluence with Willow Run	3.42	71.8	80.1	14.77
LowRR 4	Willow Run at mouth	10.95	70.7	77.4	22.69
LowRR 5	River Raisin at Gage #04176500	4.90	70.8	78.4	20.75
LowRR 6	River Raisin at confluence with Macon Creek	5.04	66.8	76.9	23.31
LowRR 7	River Raisin at confluence with Little River Raisin	14.19	63.7	73.9	58.73
LowRR 8	Camp Drain at mouth	11.01	65.5	73.3	51.17
LowRR 9	Burton and White Drain at mouth	4.18	74.4	75.8	14.13
LowRR 10	River Raisin at confluence with Camp Drain	4.43	73.1	76.7	44.23
LowRR 11	Camp Drain at mouth	7.97	68.1	76.3	24.89
LowRR 12	Kellar Drain at mouth	4.34	77.6	82.9	19.68
LowRR 13	River Raisin at confluence with Floodwood Creek	11.53	65.7	76.3	23.41
LowRR 14	Floodwood Creek at mouth	13.90	77.6	83.1	23.55
LowRR 15	River Raisin at US-223	14.05	76.4	81.1	27.66
LowRR 16	Bay Drain at mouth	5.07	77.4	82.7	14.76
LowRR 17	River Raisin at confluence with Black Creek	6.20	74.9	75.9	57.19
LowRR 18	River Raisin at Deerfield Road	4.36	69.7	73.1	20.80
LowRR 19	River Raisin at confluence with South Branch	6.32	65.7	71.7	24.75
LowRR 20	River Raisin at confluence with unnamed tributary	7.28	68.7	73.7	8.64
LowRR 21	River Raisin at confluence with Evans Creek	11.40	70.9	79.3	8.93
LowRR 22	River Raisin at Newburg Road	5.47	69.9	77.1	5.65
LowRR 23	River Raisin at downstream of island near Clinton	10.36	68.9	78.3	6.65
Macon 1	Macon Creek at mouth	3.96	65.0	80.9	8.50
Macon 2	Macon Creek at confluence with North Branch	3.61	74.4	79.6	8.02
Macon 3	North Branch Macon Creek at confluence with Bear Swamp Creek	8.85	75.4	80.3	24.31
Macon 4	North Branch Macon Creek at Hack Road	14.91	72.3	80.3	17.52
Macon 5	Bear Swamp Creek at mouth	8.44	77.5	82.0	18.38
Macon 6	Bear Swamp Creek at Petersburg Road	11.22	78.0	83.7	16.51
Macon 7	Macon Creek at confluence with South Branch	15.20	77.9	81.8	18.94
Macon 8	South Branch Macon Creek at mouth	7.74	74.8	82.2	20.09
Macon 9	South Branch Macon Creek at County Line Highway	7.12	75.1	80.8	16.05
Macon 10	Holloway, Wilson, Sutton Drains at confluence with South Branch Macon Creek	7.11	76.1	79.9	17.08
Macon 11	South Branch Macon Creek at Schreeder Brook	10.84	74.4	80.6	19.68
Macon 12	Schreeder Brook at mouth	10.12	76.2	81.8	14.49
Macon 13	Richardson Drain at mouth	6.59	78.0	83.8	11.51
Macon 14	Macon Creek upstream of Richardson Drain	11.64	77.1	83.0	24.59
Macon 15	Macon Creek at Britton Highway	7.26	73.6	80.5	9.94
Macon 16	Macon Creek at Clinton Macon Road	7.05	74.7	81.4	11.55
Saline 1	Saline River at mouth	14.29	67.3	73.3	37.92
Saline 2	Saline River at Allison Road	3.51	60.8	72.7	23.87
Saline 3	Saline River at Wabash Road	10.17	72.3	78.4	25.67
Saline 4	Saline River at confluence with outlet from Ella Lee Lake	6.98	64.2	72.0	9.28
Saline 5	Saline River at gage 04176400 and Maple Road	4.01	69.4	77.5	5.82
Saline 6	Saline River at Koch Warner Drain	3.29	71.9	78.1	5.54
Saline 7	Koch Warner Drain at mouth	12.09	70.7	77.6	13.50
Saline 8	Wood Outlet Drain at mouth	15.19	71.0	76.2	9.21

	Subbasins	Drainage Area (sq. mi.)	Runoff Curve Number		
ID	Description		1800	1978	Tc
Saline 9	Saline River at confluence with unnamed tributary	4.47	73.3	79.2	6.07
Saline 10	Unnamed tributary to Saline River at mouth	13.50	71.3	79.2	11.03
Saline 11	Saline River at Austin Road	13.54	72.8	79.1	12.05
Saline 12	Saline River at Feldkamp Road	12.41	73.0	77.4	12.39
Saline 13	Unnamed tributary to Saline River at mouth	6.04	74.2	81.2	9.26
Saline 14	Saline River at Burmeister Road	9.84	70.9	77.7	8.35
SBrRR 1	South Branch River Raisin at mouth	3.73	71.8	78.0	9.90
SBrRR 2	Cook Drain at mouth	7.77	65.0	73.6	13.63
SBrRR 3	Beaver Creek at mouth	14.46	71.9	78.9	15.36
SBrRR 4	South Branch River Raisin at confluence with Wolf Creek	5.81	67.0	80.5	14.25
SBrRR 5	Wolf Creek at mouth	15.07	71.4	79.4	18.65
SBrRR 6	Wolf Creek at confluence with Black Creek	11.28	72.6	80.8	26.89
SBrRR 7	Black Creek at mouth	8.93	74.3	81.1	17.60
SBrRR 8	Black Creek at Shepherd Road	7.01	72.1	80.8	10.36
SBrRR 9	Wolf Creek at confluence with Squaw Creek	14.95	70.6	77.3	8.46
SBrRR 10	Squaw Creek at mouth	11.41	70.6	77.6	10.26
SBrRR 11	Wolf Creek at Cambridge Lake outlet	3.69	71.7	76.1	6.34
SBrRR 12	South Branch River Raisin at US 223	14.53	67.9	78.3	12.17
SBrRR 13	South Branch River Raisin at confluence with Stony Creek	6.63	69.0	76.4	17.99
SBrRR 14	Stony Creek at mouth	13.74	74.0	79.8	16.58
SBrRR 15	South Branch River Raisin at confluence with Hazen Creek	4.38	73.6	80.8	7.70
SBrRR 16	Hazen Creek at mouth	4.67	72.3	80.3	10.32
SBrRR 17	Hazen Creek at confluence with Stoddard Drain	8.47	72.0	79.8	14.00
SBrRR 18	Stoddard Drain at mouth	11.87	71.7	79.7	12.47
SBrRR 19	South Branch River Raisin at confluence with Harrison Drain	13.04	73.3	81.3	18.90
SBrRR 20	Harrison Drain at mouth	8.03	73.9	81.6	9.56
UppRR 1	River Raisin at Allen Road	6.20	69.0	76.3	15.14
UppRR 2	River Raisin at confluence with unnamed tributary	10.03	68.9	75.8	7.82
UppRR 3	River Raisin at Ford Manchester Dam #391 Austin Road	5.02	63.4	71.7	4.45
UppRR 4	River Raisin at Manchester Mill Dam #715	11.30	63.2	71.0	13.04
UppRR 5	River Raisin at Gage #04175600	10.53	62.5	68.9	11.25
UppRR 6	River Raisin at confluence with Manchester Drain	3.72	65.6	71.6	11.64
UppRR 7	Manchester Drain at mouth	11.05	65.5	71.4	13.56
UppRR 8	Unnamed tributary to River Raisin at mouth	13.46	62.0	66.9	16.11
UppRR 9	River Raisin at confluence with unnamed tributary	3.24	67.1	71.9	8.38
UppRR 10	River Raisin at Austin Road	12.58	63.7	73.7	26.37
UppRR 11	River Raisin Tributary at Stony Lake Outlet	5.95	68.0	75.6	9.04
UppRR 12	River Raisin at confluence with Goose Creek	11.12	68.9	74.5	16.08
UppRR 13	River Raisin at confluence with unnamed tributary	12.46	68.6	72.4	20.31
UppRR 14	River Raisin at Pickerel Lake outlet	7.36	67.3	72.0	6.31
	Minimum	3.24			
	Maximum	15.20			

* calculated runoff curve number does not include Ohio, which represents 1.5 percent of the subbasin
** 1800 land cover data not available for Ohio, runoff curve number not calculated

Table B2: Ponding Adjustment

Subbasins		Ponding		50% Storm Adjustment Factor	
ID	Description	1800	1978	1800	1978
Black 1	Black Creek at mouth	97.8%	0.0%	*0.38	1.00
Black 2	Big Meadow Drain at Gorman Road, #04176110	60.7%	0.5%	0.42	0.88
Black 3	Black Creek at confluence with Bear Creek	60.0%	0.2%	0.42	0.94
Black 4	Bear Creek at mouth	97.7%	0.0%	0.38	1.00
Black 5	Gleason Brook at mouth	45.2%	1.2%	0.45	0.82
Black 6	Bear Creek at confluence with unnamed tributary	14.0%	0.0%	**	1.00
Black 7	Bear Creek at confluence with Little Bear Creek	0.6%	0.3%	**	0.92
Black 8	Little Bear Creek at mouth	0.0%	0.2%	**	0.94
Black 9	Bear Creek at confluence with unnamed tributary	0.0%	2.0%	**	0.78
Black 10	Black Creek at confluence with Nile Ditch	5.6%	0.4%	0.64	0.90
Black 11	Nile Ditch at mouth	7.2%	0.0%	0.61	1.00
Black 12	Nile Ditch at M-52	16.5%	0.2%	**	0.94
Black 13	Black Creek at confluence with unnamed tributary	18.1%	0.3%	0.54	0.92
Black 14	Bear Creek at Whaley Highway	18.3%	1.6%	0.54	0.80
Black 15	Bear Creek at Lake Hudson Dam # 467	12.4%	9.7%	0.57	0.58
Evans 1	Evans Creek at mouth	3.4%	0.4%	0.69	0.90
Evans 2	Evans Creek at Taylor/Lamkin	2.3%	1.3%	0.75	0.82
Evans 3	Taylor Creek at mouth	0.6%	1.1%	0.87	0.83
Evans 4	Lamkin Drain at mouth	20.2%	0.4%	0.53	0.90
Evans 5	Evans Creek at Wyman Road	8.4%	7.8%	0.60	0.61
Goose 1	Goose Creek at mouth	25.4%	18.5%	0.50	0.54
Goose 2	Goose Creek at Lake Columbia Outlet	19.6%	22.1%	0.53	0.52
Goose 3	Goose Creek at Little Goose Lake outlet	20.0%	16.1%	0.53	0.55
Goose 4	Goose Creek at US-12	21.0%	16.8%	0.52	0.55
Iron 1	Iron Creek at mouth	4.1%	2.0%	0.67	0.78
Iron 2	Iron Creek at Henzie Road	12.4%	10.0%	0.57	0.58
Iron 3	Iron Creek at Noggles Road	34.4%	27.1%	0.48	0.50
LitRR 1	Little River Raisin at mouth	11.2%	0.0%	0.57	1.00
LitRR 2	Swamp Raisin Creek at mouth	42.1%	0.0%	0.46	1.00
LitRR 3	Swamp Raisin Creek downstream of Schwab Drain	46.0%	0.0%	0.45	1.00
LitRR 4	Swamp Raisin Creek at Fry Drain/Garno Road	18.3%	0.0%	0.54	1.00
LitRR 5	Swamp Raisin Creek at Grosvenor Highway	3.8%	0.0%	0.68	1.00
LowRR 1	River Raisin at mouth	43.4%	9.1%	0.45	0.59
LowRR 2	Mason Run at I-75	16.9%	5.1%	0.55	0.65
LowRR 3	River Raisin at confluence with Willow Run	32.0%	5.0%	0.48	0.65
LowRR 4	Willow Run at mouth	12.4%	0.1%	0.57	1.00
LowRR 5	River Raisin at Gage #04176500	9.6%	4.7%	0.58	0.66
LowRR 6	River Raisin at confluence with Macon Creek	2.9%	0.0%	0.71	1.00
LowRR 7	River Raisin at confluence with Little River Raisin	14.3%	0.4%	0.56	0.90
LowRR 8	Camp Drain at mouth	16.4%	0.0%	0.55	1.00
LowRR 9	Burton and White Drain at mouth	75.6%	0.0%	0.40	1.00

Subbasins		Ponding		50% Storm Adjustment Factor	
ID	Description	1800	1978	1800	1978
LowRR 10	River Raisin at confluence with Camp Drain	6.6%	0.0%	0.62	1.00
LowRR 11	Camp Drain at mouth	6.3%	0.0%	0.63	1.00
LowRR 12	Kellar Drain at mouth	87.0%	0.0%	0.39	1.00
LowRR 13	River Raisin at confluence with Floodwood Creek	10.0%	0.0%	0.58	1.00
LowRR 14	Floodwood Creek at mouth	69.2%	0.1%	0.41	1.00
LowRR 15	River Raisin at US-223	48.4%	0.0%	0.44	1.00
LowRR 16	Bay Drain at mouth	79.9%	0.6%	0.40	0.87
LowRR 17	River Raisin at confluence with Black Creek	62.5%	0.7%	0.42	0.86
LowRR 18	River Raisin at Deerfield Road	17.7%	0.0%	0.54	1.00
LowRR 19	River Raisin at confluence with South Branch	28.5%	2.1%	0.49	0.77
LowRR 20	River Raisin at confluence with unnamed tributary	9.7%	2.2%	0.58	0.76
LowRR 21	River Raisin at confluence with Evans Creek	8.6%	4.1%	0.60	0.67
LowRR 22	River Raisin at Newburg Road	7.0%	0.5%	0.62	0.88
LowRR 23	River Raisin at downstream of island near Clinton	10.7%	3.6%	0.58	0.68
Macon 1	Macon Creek at mouth	1.4%	1.2%	0.81	0.82
Macon 2	Macon Creek at confluence with N Br	58.0%	0.6%	0.43	0.87
Macon 3	North Branch Macon Creek at confluence with Bear Swamp Creek	56.8%	0.0%	0.43	1.00
Macon 4	North Branch Macon Creek at Hack Road	5.8%	0.4%	0.64	0.90
Macon 5	Bear Swamp Creek at mouth	78.7%	0.0%	0.40	1.00
Macon 6	Bear Swamp Creek at Petersburg Road	82.9%	0.0%	0.39	1.00
Macon 7	Macon Creek at confluence with South Branch	75.6%	0.0%	0.40	1.00
Macon 8	South Branch Macon Creek at mouth	10.6%	0.4%	0.58	0.90
Macon 9	South Branch Macon Creek at County Line Highway	50.6%	0.2%	0.44	0.94
Macon 10	Holloway, Wilson, Sutton Drains at confluence with South Branch Macon Creek	83.7%	0.1%	0.39	1.00
Macon 11	South Branch Macon Creek at Schreeder Brook	23.0%	0.0%	0.51	1.00
Macon 12	Schreeder Brook at mouth	19.6%	0.0%	0.53	1.00
Macon 13	Richardson Drain at mouth	100.0%	0.0%	0.37	1.00
Macon 14	Macon Creek upstream of Richardson Drain	56.3%	0.0%	0.43	1.00
Macon 15	Macon Creek at Britton Highway	9.0%	0.3%	0.59	0.92
Macon 16	Macon Creek at Clinton Macon Road	12.7%	0.5%	0.57	0.88
Saline 1	Saline River at mouth	36.4%	1.9%	0.47	0.79
Saline 2	Saline River at Allison Road	12.4%	0.0%	0.57	1.00
Saline 3	Saline River at Wabash Road	34.2%	0.8%	0.48	0.85
Saline 4	Saline River at confluence with outlet from Ella Lee Lake	3.9%	0.3%	0.68	0.92
Saline 5	Saline River at gage 04176400 and Maple Road	10.8%	0.6%	0.58	0.87
Saline 6	Saline River at Koch Warner Drain	19.3%	1.1%	0.53	0.83
Saline 7	Koch Warner Drain at mouth	9.9%	3.3%	0.58	0.69
Saline 8	Wood Outlet Drain at mouth	25.2%	1.8%	0.51	0.79
Saline 9	Saline River at confluence with unnamed tributary	30.0%	0.7%	0.49	0.86
Saline 10	Unnamed tributary to Saline River at mouth	15.3%	2.3%	0.55	0.75
Saline 11	Saline River at Austin Road	15.3%	0.6%	0.55	0.87
Saline 12	Saline River at Feldkamp Road	37.2%	1.1%	0.47	0.83

Subbasins		Ponding		50% Storm Adjustment Factor	
ID	**Description**	**1800**	**1978**	**1800**	**1978**
Saline 13	Unnamed tributary to Saline River at mouth	22.4%	0.6%	0.52	0.87
Saline 14	Saline River at Burmeister Road	11.1%	2.3%	0.57	0.75
SBrRR 1	South Branch River Raisin at mouth	16.2%	0.8%	0.55	0.85
SBrRR 2	Cook Drain at mouth	13.0%	0.5%	0.57	0.88
SBrRR 3	Beaver Creek at mouth	18.3%	0.6%	0.54	0.87
SBrRR 4	South Branch River Raisin at confluence with Wolf Creek	2.9%	0.4%	0.71	0.90
SBrRR 5	Wolf Creek at mouth	4.5%	2.0%	0.66	0.78
SBrRR 6	Wolf Creek at confluence with Black Creek	9.3%	1.2%	0.59	0.82
SBrRR 7	Black Creek at mouth	16.3%	0.8%	0.55	0.85
SBrRR 8	Black Creek at Shepherd Road	18.0%	1.2%	0.54	0.82
SBrRR 9	Wolf Creek at confluence with Squaw Creek	18.2%	13.7%	0.54	0.56
SBrRR 10	Squaw Creek at mouth	17.4%	4.3%	0.54	0.67
SBrRR 11	Wolf Creek at Cambridge Lake outlet	28.2%	25.6%	0.49	0.50
SBrRR 12	South Branch River Raisin at US 223	4.2%	2.8%	0.67	0.72
SBrRR 13	South Branch River Raisin at confluence with Stony Creek	15.2%	2.0%	0.55	0.78
SBrRR 14	Stony Creek at mouth	35.7%	1.6%	0.47	0.80
SBrRR 15	South Branch River Raisin at confluence with Hazen Creek	26.5%	3.2%	0.50	0.70
SBrRR 16	Hazen Creek at mouth	18.2%	1.2%	0.54	0.82
SBrRR 17	Hazen Creek at confluence with Stoddard Drain	7.3%	1.8%	0.61	0.79
SBrRR 18	Stoddard Drain at mouth	2.2%	1.0%	0.76	0.83
SBrRR 19	South Branch River Raisin at confluence with Harrison Drain	8.7%	0.5%	0.60	0.88
SBrRR 20	Harrison Drain at mouth	15.6%	1.2%	0.55	0.82
UppRR 1	River Raisin at Allen Road	11.1%	0.5%	0.57	0.88
UppRR 2	River Raisin at confluence with unnamed tributary	7.6%	1.9%	0.61	0.79
UppRR 3	River Raisin at Ford Manchester Dam #391 Austin Road	11.0%	7.9%	0.58	0.61
UppRR 4	River Raisin at Manchester Mill Dam #715	16.3%	6.3%	0.55	0.63
UppRR 5	River Raisin at Gage #04175600	11.5%	3.8%	0.57	0.68
UppRR 6	River Raisin at confluence with Manchester Drain	18.9%	2.9%	0.54	0.71
UppRR 7	Manchester Drain at mouth	20.8%	13.9%	0.52	0.56
UppRR 8	Unnamed tributary to River Raisin at mouth	28.4%	11.1%	0.49	0.57
UppRR 9	River Raisin at confluence with unnamed tributary	27.3%	13.8%	0.50	0.56
UppRR 10	River Raisin at Austin Road	15.6%	11.5%	0.55	0.57
UppRR 11	River Raisin Tributary at Stony Lake Outlet	26.5%	16.4%	0.50	0.55
UppRR 12	River Raisin at confluence with Goose Creek	31.1%	20.3%	0.49	0.53
UppRR 13	River Raisin at confluence with unnamed tributary	28.8%	19.9%	0.49	0.53
UppRR 14	River Raisin at Pickerel Lake outlet	23.2%	13.7%	0.51	0.56

* calculated ponding does not include Ohio, which represents 1.5 percent of the subbasin
** 1800 land cover data not available for Ohio, ponding adjustment not calculated

Appendix C: Glossary

Aggrade - to fill and raise the level of a stream bed by deposition of sediment.

Alluvium - sediment deposited by flowing rivers and consisting of sands and gravels.

Bankfull discharge - that discharge of stream water that just begins to overflow in the active floodplain. The active floodplain is defined as a flat area adjacent to the channel constructed by the river and overflowed by the river at recurrence interval of about 2 years or less. Erosion, sediment transport, and bar building by deposition are most active at discharges near bankfull. The effectiveness of higher flows, called over bank or flood flows, does not increase proportionally to their volume above bankfull in a stable stream, because overflow into the floodplain distributes the energy of the stream over a greater area. See also channel-forming and effective discharge.

Base Flow - the part of stream flow that is attributable to long-term discharge of groundwater to the stream. This part of stream flow is not attributable to short-term surface runoff, precipitation, or snow melt events.

Best Management Practice (BMP) - structural, vegetative, or managerial practices used to protect and improve our surface waters and groundwaters.

Channel-forming Discharge - a theoretical discharge which would result in a channel morphology close to the existing channel. See also effective and bankfull discharge.

Condensation - phase change of water vapor into liquid droplets.

Critical Areas - the geographic portions of the watershed contributing the majority of the pollutants and having significant impacts on the waterbody.

Critical Depth - depth of water for which specific energy is a minimum.

Curve Number - see Runoff Curve Number.

Design Flow - projected flow through a watercourse which will recur with a stated frequency. The projected flow for a given frequency is calculated using statistical analysis of peak flow data or using hydrologic analysis techniques.

Detention - practices which store stormwater for some period of time before releasing it to a surface waterbody. See also retention.

Dimensionless Hydrograph - a general hydrograph developed from many unit hydrographs, used in the Soil Conservation Service method.

Direct Runoff Hydrograph - graph of direct runoff (rainfall minus losses) versus time.

Discharge - volume of water moving down a channel per unit time. See also channel-forming, effective, and bankfull discharge.

Drainage Divide - boundary that separates subbasin areas according to direction of runoff.

Effective Discharge - the calculated measure of channel forming discharge. This calculation requires long-term water and sediment measurements, although modeling results are sometimes substituted. See also channel-forming and bankfull discharge.

Ephemeral Stream - a stream that flows only during or immediately after periods of precipitation. See also intermittent and perennial streams.

Evaporation - phase change of liquid water to water vapor.

Evapotranspiration - the combined process of evaporation and transpiration.

Field Capacity - the amount of water held in soil after gravitational water is drained.

First Flush - the first part of a rainstorm that washes off the majority of pollutants from a site. The concept of first flush treatment applies only to a single site, even if just a few acres, because of timing of the runoff. Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet.

Flashiness - has no set definition but is associated with the rate of change of flow. Flashy streams have more rapid flow changes.

Flood Hazard Zone - area that will flood with a given probability.

Flux - the volume of fluid crossing a unit cross-sectional surface area per unit time.

Groundwater - that part of the subsurface water that is in the saturated zone.

Headwater Stream - the system of wetlands, swales, and small channels that mark the beginnings of most watersheds.

Hydraulic Analysis - an evaluation of water elevation for a given flow based on channel attributes such as slope, cross-section, and vegetation.

Hydrograph - graph of discharge versus time.

Hydrologic Analysis - an evaluation of the relationship between stream flow and the various components of the hydrologic cycle. The study can be as simple as determining the watershed size and average stream flow, or as complicated as developing a computer model to determine the relationship between peak flows and watershed characteristics, such as land use, soil type, slope, rainfall amounts, detention areas, and watershed size.

Hydrologic Cycle - When precipitation falls to the earth, it may:

- be intercepted by vegetation, never reaching the ground.
- infiltrate into the ground, be taken up by vegetation and evapotranspirated back to the atmosphere.
- enter the groundwater system and eventually flow back to a surface water body.

- runoff over the ground surface, filling in depressions.
- enter directly into a surface waterbody, such as a lake, stream, or ocean.

When water evaporates from lakes, streams, and oceans and is re-introduced to the atmosphere, the hydrologic cycle starts over again.

Hydrology - the occurrence, distribution, and movement of water both on and under the earth's surface. It can be described as the study of the hydrologic cycle.

Hyetograph - graph of rainfall intensity versus time.

Impervious - a surface through which little or no water will move. Impervious areas include paved parking lots and roof tops.

Infiltration Capacity - rate at which water can enter soil with excess water on the surface.

Interflow - flow of water through the upper soil layers to a ditch, stream, etc.

Intermittent Stream - a stream that flows only during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year. See also ephemeral and perennial streams.

Invert - bottom of a channel or pipe.

Knickpoint - a point of abrupt change in bed slope. If the streambed is made of erodible material, the Knickpoint, or downcut, may migrate upstream along the channel and have undesirable effects, such as undermining bridge piers and other manmade structures.

Lag Time - time from the center of mass of the rainfall to the peak of the hydrograph.

Losses - Rainfall that does not runoff, i.e. rainfall that infiltrates into the ground or is held in ponds or on leaves, etc.

Low Flow - minimum flow through a watercourse which will recur with a stated frequency. The minimum flow for a given frequency may be based on measured data, calculated using statistical analysis of low flow data, or calculated using hydrologic analysis techniques. Projected low flows are used to evaluate the impact of discharges on water quality. They are, for example, used in the calculation of industrial discharge permit requirements.

Morphology - the study of the form and structure of a river, stream, or drain.

Nonpoint Source Pollution - pollutants carried in runoff characterized by multiple discharge points. Point sources emanate from a single point, generally a pipe.

Overland Flow - see Runoff.

Peak Flow - maximum flow through a watercourse which will recur with a stated frequency. The maximum flow for a given frequency may be based on measured data, calculated using statistical analysis of peak flow data, or calculated using hydrologic analysis techniques. Projected peak flows are used in the design of culverts, bridges, and dam spillways.

Perched Ground Water - unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone.

Perennial Stream - a stream that flows continuously during both wet and dry times. See also ephemeral and intermittent streams.

Precipitation - water that falls to earth in the form of rain, snow, hail, or sleet.

Rating Curve - relationship between depth and amount of flow in a channel.

Recession Curve - portion of the hydrograph where runoff is from base flow.

Retention - practices which capture stormwater and release it slowly though infiltration into the ground. See also detention.

Riparian - pertaining to the bank of a river, pond, or small lake.

Runoff - flow of water across the land surface as surface runoff or interflow. The volume is equal to the total rainfall minus losses.

Runoff Coefficient - ratio of runoff to precipitation.

Runoff Curve Number - parameter developed by the Natural Resources Conservation Service (NRCS) that accounts for soil type and land use.

Saturated Zone - (1) those parts of the earth's crust in which all voids are filled with water under pressure greater than atmospheric; (2) that part of the earth's crust beneath the regional water table in which all voids, large and small, are filled with water under pressure greater than atmospheric; (3) that part of the earth's crust beneath the regional water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

Scarp - the sloped bank of a stream channel.

Sediment - soil fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice.

Sinuosity - the ratio of stream length between two points divided by the valley length between the same two points.

Simulation Model - model describing the reaction of a watershed to a storm using numerous equations.

Soil - unconsolidated earthy materials which are capable of supporting plants. The lower limit is normally the lower limit of biological activity, which generally coincides with the common rooting of native perennial plants.

Soil Moisture Storage - Volume of water held in the soil.

Stochastic - model that contains a random component.

Storage Delay Constant - parameter that accounts for lagging of the peak flow through a channel segment.

Storage-Discharge Relation - values that relate storage in the system to outflow from the system.

Stream Corridor - generally consists of the stream channel, floodplain, and transitional upland fringe.

Subbasins - hydrologic divisions of a watershed that are relatively homogenous.

Synthetic Design Storm - rainfall hyetograph obtained through statistical means.

Synthetic Unit Hydrograph - unit hydrograph for ungaged basins based on theoretical or empirical methods

Thalweg - the "channel within the channel" that carries water during low-flow conditions.

Time of Concentration - time at which outflow from a basin is equal to inflow or time of equilibrium.

Transpiration - conversion of liquid water to water vapor through plant tissue.

Tributary - a river or stream that flows into a larger river or stream.

Unit Hydrograph - graph of runoff versus time produced by a unit rainfall over a given duration.

Unsaturated Zone - the zone between the land surface and the water table which may include the capillary fringe. Water in this zone is generally under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies, the water pressure locally may be greater than atmospheric.

Vadose Zone - see Unsaturated Zone.

Watershed - area of land that drains to a single outlet and is separated from other watersheds by a divide.

Watershed Delineation - determination of watershed boundaries. These boundaries are determined by reviewing USGS quadrangle maps. Surface runoff from precipitation falling anywhere within these boundaries will flow to the waterbody.

Water Surface Profile - plot of the depth of water in a channel along the length of the channel.

Water Table - the surface of a groundwater body at which the water pressure equals atmospheric pressure. Earth material below the groundwater table is saturated with water.

Yield - peak flow divided by drainage area